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A POLITICAL THEORY OF WATER GOVERNANCE

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About the Author

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A Political Theory of Water Governance

David G Victor[1]
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The energy industry is a major user of water and also central to the energy-intensive processes of purifying and transporting water. However, the industry is not the only sector that uses water, and looking worldwide there are huge variations in how policy makers treat different sectors even when they draw upon the same water resources. Moreover, hardly any country adopts "rational" management of water resources; instead, water problems are routinely ignored until they reach crisis proportions. Officials responsible for governing water uses and quality often embrace policy instruments, such as under-pricing of water and command and control regulation, that are highly inferior to best practices. This paper outlines a theory that can explain these broad dysfunctions and illustrates the theory with vignettes from the Middle East, China and the Southwestern U.S. It also explores some implications for widely discussed water reforms and for scholars who build models designed to simulate water-using behavior.

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In nearly all countries, fresh water resources are under increasing stress. While the sources of stress are many, the energy industry plays a particularly important role. The energy industry is the world's second largest net user of fresh water (agriculture is first). And the industry is the largest source of water withdrawals—mostly in the form of cooling water that is returned (a bit warmer) after use. In both use and withdrawal, policy makers are scrutinizing more closely the many impacts of the energy industry on water. This essay explores how that pressure is likely to arise and be translated into practical "governance."[2] In addition to its intrinsic importance to water matters, a focus on the energy industry also helps to reveal fundamental forces at work in the governance of scarce water resources.

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[1] A special thanks to Linda Wong and Fang Rong for research assistance and to BP, plc, EPRI and the Norwegian Research Foundation for funding to UCSD's Laboratory on International Law and Regulation (ilar.ucsd.edu).

[2] We use governance in the broadest sense, consistent (for example) with the Global Water Partnership and UNDP which has defined "water governance" as "the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society." (Rogers and Hall, 2003)

Throughout, this essay will make 4 major points. First, while there is tremendous technical potential for reducing energy and other industrial impacts on water resources, actually realizing those potentials will hinge on governance. In one vision of governance, societies identify water stresses in advance and respond with policy incentives that give firms and other users of water resources the flexibility to adjust and find the least cost means of controlling their impacts. That model—what I will call "Model 1"—is a lovely vision that rarely exists in the real world. Instead, an alternative "Model 2" is what usually prevails. In this alternative vision, water resource stresses are ignored until they become acute. Policy instruments are prescriptive and not flexible. Industries are regulated independently as "silos" rather than allowing for more efficient trading across industries and space. Model 1 is not a straw man—in fact, most of the economic-engineering models that are used to examine water scarcity adopt Model 1 views of the world. One goal of this paper is to articulate the key elements of Model 2 so that we can improve the analytical tools that are used to examine real world water stresses and governance responses.

Second, I will suggest that the biggest inefficiencies in Model 2—the tendency for societies to ignore water stresses until they become acute and the strong bias in favor of "command and control" regulation over more flexible markets—are deeply rooted in human cognition and political economy. They will be very hard to fix. Success in clearing these barriers is likely to arise only in special niches, which helps to explain why the real world experience using flexible modes of regulation in water resources are limited in scope. Most use of flexible water markets, for example, arises in a "hybrid" form in which water markets are created only for relatively few water users while the rest are subjected to traditional regulation. There has been enormous political attention to the political difficulties in getting water prices to better reflect real world scarcity. A more politically sophisticated vision of how governance systems actually operate could help explain why mis-pricing and mis-management of water is so pervasive.

Third, I will suggest that there is tremendous promise in popular new ideas for water governance—notably integrated water resources management (IWRM). However, the optimism about IWRM must be tempered by realities about how integration across many different industries and political systems might actually be achieved. IWRM—and other basin-wide management schemes—is likely to be layered on top of existing governance systems rather than replace them. Without politically difficult efforts to remove existing systems of governance while implementing new IWRM schemes, the result, I suggest, is likely to be more fragmented governance.

Fourth, I will argue that while these political challenges for efficient governance are significant where governors focus on water quantities, the problems are likely to be even greater as more jurisdictions focus on water quality such as temperature, pollution loads, seasonal flows and complex interactions between the uses of fresh water for human and natural purposes. These new missions are

difficult to manage because they necessarily work across multiple government agencies, each with their own objective.

Together, these four arguments suggest that "governance" factors are likely to explain why real world outcomes in fresh water management could be radically different from the economically optimal potential. These insights may also be applicable to other natural resources that societies manage, such as forests, wilderness and open access fisheries.

I proceed in three steps.

First, I examine how societies identify problems and mobilize the resources needed to govern them. Many studies suggest that society should be more forward-looking in this process and less prone to wait until a crisis appears. I suggest that crisis-mode decision-making actually helps political systems address some of their greatest challenges, such as processing information that is laced with uncertainty and mobilizing scarce resources like financial capital and ephemeral attention of voters and politicians.

Not only is society prone to sub-optimal behavior in responding to natural resource crises, but the choice of policy instruments is also prone to be far from optimal. I examine the policy instruments that societies deploy when addressing such problems—in particular, the choice between "command and control" and market-based instruments such as prices and tradable quotas. I argue that command-and-control systems have large political benefits that help explain why they are so persistent, despite all the evidence that favors market approaches. Command and control systems allow politicians to channel the benefits of regulation toward powerful and well-organized groups while diffusing the costs across less suspecting entities. And for many firms that view water management as a problem of compliance rather than strategy, command-and-control systems make compliance easier to assure.

Second, I use this simple model of political economy—which informs the timing of policy responses and the choice of policy instrument—to illustrate real world evolution of water policy in three macro regions of the world: China, the arid Middle East, and the southwestern U.S. It is impractical in a single paper to do justice to the complexity of each of these case studies, but in my analysis I will focus on a few key elements of each. Those include the question of which forces actually drive reforms; the role of markets; and the ways that fragmentation of property rights and administrative bodies are managed.

Third, I look to the future and the possible use of new governance systems such as IWRM across whole basins and industries. I examine the incentives for politically powerful actors to adopt these kinds of mechanisms and, in particular, focus on the persistent difficulties that have arisen as governance systems for water have tried to encourage trading and flexibility across industries.

1: The Puzzle: Why Do Societies Consistently Choose Inefficient Forms of Governance?

Other papers presented at this conference will show that there already exists a wide array of technical solutions to problems of water scarcity and quality. In energy, those solutions include dramatic improvements in the efficiency with which water resources are withdrawn and used.[3] Outside the energy sector, notably in agriculture, opportunities abound as well.[4] At the same time, there is mounting evidence that many regions in the world are facing severe and growing challenges in water supply.[5] Those challenges are particularly notably in the portions of the world economy—such as China and India—that are growing most rapidly. Climate change, it is likely, will make these problems even more severe. A warmer world is likely to be a wetter world overall, but the distribution of fresh water supplies is likely to change radically. River basins that depend on high altitude snowpack—including the basins in China, India and the southwestern US already under stress—are likely to fare worse as the climate warms.

Thus we face a puzzle. Water scarcity and degradation of quality is a looming problem that, in most settings, is prone to get worse. The solutions are at hand and yet the actual adoption of better governance systems—such as the use of market-based forces and the re-allocation of water resources to more productive uses in the economy—is rare. When societies do shift their systems of governance it is often under duress even though earlier and more orderly shifts would be economically much more efficient. This section aims to explain that puzzle. It offers a simple model of how political, cognitive and economic forces interact to yield governance failures.

Resolving this puzzle requires looking at how political action within societies is typically organized. I work on three fronts: rigidity, crisis and the choice of policy instruments.

Rigidity: The Incumbent's Advantage

Most political systems are organized to create tremendous advantages for incumbents. In general, incumbents know who they are and are well-organized; by contrast new interests and the broad public interest is more highly diffuse and less capable of mobilizing political pressure.[6] Over time, new technologies that allow for more widespread diffusion of information may have shifted the balance of influence

[3] cite eventually to BP Handbook when published
[4] cites to conference papers.
[5] Saeijs and Van Berkel, 1995
[6] Olson, 1965; Stigler, 1971

away from incumbents and toward the purveyors of new ideas and the broader public. But that theory of democratization is still a work in progress and there is ample evidence that incumbents still carry a huge advantage.

Political systems that reward incumbency—that is, pretty much every political system on the planet--creates rigidity because politically powerful groups organize to defend the status quo. Rigidity, however, is not merely the result of fundamental political forces at work. It is also hard wired into the human brain. Cognitive psychologists and behavioral economists have studied, for example, the "endowment effect" by which humans prize items that are within their grasp and familiarity and avoid actions that would alter the status quo.[7] The endowment effect is tightly bound with high levels of risk aversion. In an ideal world in which political choices involving risk and reform are made with full rationality, people would assess risks symmetrically. In the real world where humans focus on their existing endowments, the evaluation of risk and opportunity are done highly asymmetrically. Put differently, people are highly averse to choices that might lead to losses. There is some evidence that elite experts—those who tend to control many features of the policy making process—are less susceptible to asymmetrical reasoning.[8] But experts must respond, in most societies, to public pressures; and reasoning in the broader public is heavily influenced by endowment effects and loss aversion. Uncertainty about the benefits of a change in the status quo amplifies these tendencies.

Crisis

The strong bias in favor of the status quo helps to explain, as well, why change tends to arrive during crisis. For policy makers interested in shifting to new, improved forms of governance, crisis offers at least three huge advantages over politics in normal times.

One advantage is psychological. In times of crisis—when existing modes of decision making are demonstrably failing—risk aversion and the power of endowment effects can diminish. In the extreme, when decision makers see that their status quo has failed, their approach to risk actually reverses—they imagine that new approaches will work better than is likely. Compared with the status quo, any change is seen as a gain. And in the realm of gains, there are strong cognitive biases to ignore the risks of change.

A second advantage of crisis is political defeat for incumbents. This is often evident in whole political systems wrenched by crisis—for example, a massive financial crisis in 1991 led to turmoil in the Indian political system and the rise to power of a technocratic market-oriented government. That government adopted

[7] Kahneman and Tversky, 1979

[8] For a review of the cognitive biases and how they affect expert versus non-expert reasoning see Hafner-Burton et al., 2013.

reforms that were inconceivable under the earlier ossified system of government. Newly empowered reformers didn't fix all of India's ills, of course—they started by focusing on more immediate problems and on problems that were within their grasp—but over time a new approach to policy making gained credibility. Disruptive political change does not always favor markets, of course—the Chavez-led revolution in Venezuela, for example, took power in a democratic election in 1998 by promising populist and anti-market reforms.

A third advantage of crisis is the opportunity for mass mobilization. Much politics in normal times revolves around organized interest groups devising ways to shift power and resources to themselves and away from interest groups—especially the broader public—that may be less well organized. Visible failure of the status quo can inspire broad-based political movements, especially as it is often easier to rally masses around conspicuous failure of incumbents than around complex new ideas for governing. Some of the most massive reforms in Brazil's electric power system arose in the wake of the 2001 blackouts that were the result of incumbent operators who protected vested interests within the hydro industry by under-charging for the use of water that flowed through hydro dams. The reforms created auctions for new electric power supplies, new pricing schemes that cut consumption of electricity, and more independent regulators. Prior to the blackout the public had not much focused on the electric power system; during and after the blackout it was a national obsession.[9]

Together these advantages of crisis help explain why political changes tend to arise in punctuated form. In the noise of normal policy making, evidence accumulates that the existing system isn't working. Those anomalies can lead to intellectual revolutions and, at times, even physical ones.[10] Societies need focal points to embrace complex changes in policy, especially when those changes harm the interests of powerful incumbents.

The Choice of Policy Instruments

The scarcity and degradation of water resources is hardly a unique problem in the management of natural resources. A substantial body of theory and real world experience with the design of optimal policy instruments has emerged. That scholarship points to the value of using market-based policy instruments rather than "command and control" because markets allow for more flexibility to innovate and to reallocate resources to the most productive sectors of the economy.[11] The exact choice of market-based instrument—whether taxes on consumption and pollution of tradable quotas—does not much matter in a world where information is relatively inexpensive and transaction costs are low.[12] But where information

[9] De Oliveira, 2007
[10] Hall, 1993
[11] Stavins, 1988
[12] Weitzman, 1974

about costs and impacts is imperfect—such as in the real world—priced-based policies (e.g., pollution taxes) are often preferable because they created predictability in costs.[13] Tradable quotas work well when trading systems are highly efficient and barriers to entry are low.

Thus there is a ordering of preferences—on the basis of economic theory—for the choice of policy instrument. Markets are preferred over command; within the realm of markets, prices are preferred over quotas. But what actually occurs in the real world offers a puzzle. Almost exactly the opposite outcome is usually evident. Command and control regulation is the norm. Where markets are used—for example, tradable water quotas—those markets are designed to impede full trading rather than allow the market to yield whatever outcome is most efficient. And full cost pricing—the best option in most water-related resource management situations—is rarely used.

The explanation for these odd choices lies with political organization. While command and control regulation is costly, it offers huge advantages to the players who are well organized—the incumbent users of a water resource and the regulators. For incumbents, regulatory pressure can be a source of advantage by creating barriers to entry. Operationally, command and control regulation also offers tremendous advantages to regulated enterprises because it allows them to treat regulatory pressure as a problem of compliance that can be delegated to a subdivision of the company and ignored so long as that subdivision performs well. Regulators, too, see many advantages in command and control regulation, for they are the agents of a political system that is buffeted by many different interest groups. They must deliver benefits to those groups, and regulation offers a clear path with visible outcomes—pollution standards set, technologies required, and fines levied. For both sides, the sclerosis of command and control regulation is its most prized asset.

Tradable quotas can produce many of the same predictable benefits to regulators and to enterprises if the market trading system is restrained. Incumbents don't benefit from trading if all the tradable assets are re-auctioned every few years. Regulators who are attuned to the interests of their principals won't benefit from a market system if fresh auctions continuously create a new array of principals. Thus we witness trading systems that are designed to reinforce incumbents—systems without fresh auctions of quotas (often with legal bans on such trading) and with large impediments for existing quota-holders to re-sell their assets.

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[13] The full story is more complicated. For pollution or depletion problems for which there are known thresholds, a quota-based market system can be preferred because quotas can be set to avoid the dangerous threshold. Most water-based depletion and degradation problems are not of that type.

By far, the least attractive option politically is the one that economic theory tells us will be best: prices. For incumbents and regulators, alike, a price mechanism is highly undesirable. Incumbents pay the highest costs under such systems, and even if government promises to recycle the revenue back into the industry, the incumbent can't be sure that promise is credible. (A long string of broken promises is good evidence that government can't keep its word on fiscal matters without some external enforcement.) New entrants are highly advantaged by pricing mechanisms because their costs scale only when their enterprise scales, and if new entrants arrive with a superior production method they see a visible competitive advantage right at the outset. Regulators, too, will not prefer pricing mechanisms since the very transparency of a price schedule makes it hard to channel benefits to principals. (The lack of much to do but monitoring and enforcing a levy must also be a deterrent to the regulatory entrepreneur who seeks budget, personnel and stature.)

Thus we have a very simple political economy model that can begin to explain some of the major fears of real-world regulation on complex, costly matters. While I will illustrate this model in the case of water depletion and degradation, the same model is useful in many other settings as well. The model explains why policy reforms arise in crisis rather than more efficiently sequenced over time. And it explains why policy instruments that are preferred are almost exactly the opposite of what economic theory suggests will be best.

This model also helps explain the sequencing of policy instruments over time. Command and control instruments may be preferred, but they have large known inefficiencies. When incumbent groups weight those inefficiencies heavily they seek reform, and the result is more flexible regulatory systems that preserve the advantages of incumbency but allow for some application of market forces at the margin. Elsewhere I have called these "hybrid markets" or "potemkin markets"—they are governance systems in which incumbents have secure advantages because the core of governance is managed by command with flexible market-oriented incentives layered on top. In many settings, they are designed to look like markets to the outside when, in fact, the central function of a market (allocation of resources) is quite different. An interesting example, today, is the European Union's efforts to control emissions of greenhouse gases. The most visible elements of that system is the Emission Trading Scheme (ETS), but in fact the ETS has almost no practical impact on emission patterns—a wide array of other policy instruments, such as regulations on plant efficiency, feed-in tariffs for renewable power sources, soft budget constraints for nuclear plants and the like have a larger practical impact on actual emissions patterns.

2: Some Illustrations and Case Studies

The real world is a complicated place. What follows are some illustrations drawn from three regions—the Middle East, China and the Southwestern U.S.—that

all face severe water shortages (and problems of water quality) and thus are good testbeds for illustrating how water governance evolves in the real world. Each of these cases is complex; each has a large role for many local factors. But looking across the cases suggests that real world policy evolution is much more aligned with the political economy model I have offered—policy evolution through crisis and persistent suboptimal choice of policy instruments—than the ideal "Model 1" vision of the world.

The cases offered here are vignettes, not full blown case studies. When looking at the Middle East I focus on the factors that explain variation in how different countries from that region have managed water resources since that variation, I will suggest, reveals a lot about the central role of public institutions in explaining why some countries manage water problems relatively well and others fail. I focus, in particular, on how the Middle Eastern countries have addressed what is always one of the greatest challenges in water management: paying for and managing water infrastructures. When looking at China I examine the challenge that is often paramount in large countries: dealing with the problem of fragmentation. And in the United States I look at how different schemes for allocating property rights across different jurisdictions affect the design and operation of water markets.

Middle East

To some observers, water is the centerpiece of Middle Eastern politics while others hold that water is structurally insignificant to most of the political forces at work in the region.[14] There is little doubt that across the region pressures on water resources are mounting and likely to get worse with climate change.[15]

As in most of the world, governments in the region have focused on large supply-side projects such as desalination and dam construction and less on an adaptive approach that emphasize important "soft" factors such as managing water demand and improving the efficiency of water use. The UN's Middle East and North Africa (MENA) region is the driest in the world with only 1% of the world's available freshwater. Eight of the 11 countries in this region are considered water scarce and 2 are water stressed.[16] Regionally, 12% of the population lacked access to safe water and 25% did not have access to sanitation.[17] With a rapidly growing urban population, housing shortages, and inadequate infrastructure, informal settlements have sprouted in urban areas, further straining already water scarce cities throughout this region. Few of these informal communities receive water and

[14] Selby, 2005
[15] Sowers, Vengosh, and Weinthal, 2011
[16] Pérard, 2008
[17] SWI, Tropp, and Jägerskog, 2006

wastewater services.[18] The failure of public services in many countries of MENA has led to a phenomena now evident in much of the world where government does not perform—the rise of private markets. In poorly served MENA settlements, residents often buy water sold by private vendors and pay 10-20 times more per litre of water than residents who receive piped service.[19] These hybrid markets—where utility piped service is widespread but performs poorly and layered on top are private markets with much more reliable but costly service that can't take advantage of the scale economies of a well functioning utility network—are commonplace in the region.

There is a large mismatch between pricing and scarcity, especially in the sector that uses most fresh water: agriculture. More than 65% of water withdrawal in the region goes to agriculture, in line with other developing countries but significantly more than the 33% and 38% for agriculture in Europe and North America, respectively, where about half of water withdrawal is for industrial use.[20] Studies that have tried to track value-added of different sectors of the economy and the efficiency with which they use water conclude that agriculture is generally highly wasteful and industry in general is much more efficient in how it uses water—a pattern that relates directly to huge differentials in pricing for water resources. [21]

Recently the OECD led a region-wide assessment of water policies in the MENA region and identified an array of common challenges across the region as well as massive variation in the extent to which different national governing systems have addressed those challenges adequately.[22] Whether the countries began reforming their water sector decades ago, like Morocco and Tunisia, or they are just beginning, they all face important institutional challenges. All face the challenge that is evident essentially everywhere in the world: the need to mobilize massive infrastructure investment in water supply and treatment systems that, at present, charge low fixed prices. The OECD analysis tabulated a large number of water governance challenges, in particular:

- Limited enforcement of water policies
- Overlapping responsibilities between different institutions with unclear roles
- Unclear legislative and regulatory frameworks at the national level, which creates coordination problems at the local and regional levels
- Lack of an effective strategy to manage water demand growth

[18] Faruqui, 2003
[19] Faruqui, 2003
[20] Pérard, 2008
[21] Pérard, 2008
[22] OECD, 2010

- Inadequate human resources capacity in government agencies and insufficient awareness of water issues among the general population
- Insufficient mechanisms to ensure stakeholders' participation

Countries that have done well in managing these problems have not been the richest in the region, such as the large oil exporters. These countries have been able to manage water scarcity and quality problems by showering them with costly infrastructures. Instead, the most innovative countries have generally been those that are the smallest and most vulnerable and those that tend to score well on other measures of water governance. In general, better performing countries have also been those that are exposed (and prone to brace) external ideas. For example, Morocco has adopted a model for basin-wide watershed management similar to the centralized watershed agencies developed in France, Spain, and other OECD countries.[23]

In addition to OECD's work, other studies have also examined the region carefully and come to similar conclusions. One particularly interesting set of insights concerns the effects of religion on water management. Morill and Simas (2009)[24] compare the water laws in Egypt, Jordan, Lebanon, Morocco, Oman, Tunisia, and Yemen in the context of religious and customary law.

In the predominantly Muslim countries in the MENA region, Islamic principles that address water resources present an additional challenge to solving the water-scarcity issue. The challenge is "in aligning Islamic and customary law with the realities of modern day water resources management (WRM) law and policy."[25] Islamic religious law, or Shari'a, as spelled out in the text of the Qu'ran, regulates all human actions, including the use of water resources. The Qu'ran says that "water is a gift of God and in principle belongs to the community" and all individuals and domesticated livestock have a right of *shafa* ("drink").[26] Some Muslims believe that Islam prohibits the selling of water.[27] Morill and Simas point out that, for the reason of the right of *shafa*, water pricing is one of the most difficult parts of water law to implement.

Full privatization of water, where a private company owns the water rights, is unlikely to be permissible in Islam.[28] (Of course, full privatization of water infrastructure is rare everywhere in the world because of the severe risks to private investors from owning an asset that is highly politicized.) While ownership may prove problematic, a wide array of legal forms, such as service and lease contracts

[23] OECD, 2010
[24] Morill and Simas, 2009
[25] Morill and Simas, 2009
[26] Morill and Simas, 2009
[27] Faruqui, 2003
[28] Faruqui, 2003

or build operate transfer (BOT) schemes, are viable.[29] Comparing across the region, Morocco, Jordan, and Algeria are the most "active" users of such schemes: Jordan is the largest user of private suppliers with about 40% of its population relying on private providers for drinking water (as of 2006); Morocco, through awarding concession contracts, is the most active in outsourcing water supply; and Algeria signed a BOT contract for a desalination plant in 2001 and outsourced the water supply of Algiers through a management contract in 2005.[30] Private operators have operated in these countries since the late 1990s. In Egypt, Lebanon, Turkey, and Palestine, private sector involvement in water supply is low but increasing, while private sector presence is non-existent in Tunisia, Syria, Cyprus, and Malta.[31] As with private ownership in many other network industries, delegation to private actors does not necessarily improve efficiency unless appropriate incentives are in place as well as institutions such as independent regulatory agencies.[32] Looking across the region, the actual performance of water systems correlates less with ownership and the presence of markets and more with the quality of governing institutions.

In countries that have relied on public ownership and management of public agencies, Tunisia is a model. In the Mediterranean region, Tunisia is one of the countries with the greatest water scarcity. The country sees irregular annual precipitation and "renewable freshwater available per inhabitant is 50% below the water scarcity standard."[33] The country faces additional challenges in the remoteness of its water resources to where the water is consumed and low quality of water. The two public agencies that manage the water and sanitation sectors and the two national agencies that oversee large infrastructure projects and water resource management are highly centralized and very politicized but their performance has also been impressive. Tunisia has one of the lowest rates (18.2%) of unaccounted for water in the region; 100% of urban residents have access to safe drinking water with a household connection rate of 98%; in contrast to other cities in the region, Tunisian cities usually have continuous water supply; and their bill collection rate is over 99%.[34]

The Water Code of 1975 (updated most recently in 2001) regulates resources, planning and development, tariff rates, and the reuse and conservation of water. Since 2000 Tunisia has followed an integrated water resources management (IWRM) approach alongside the further development of the country's water

[29] Pérard, 2008
[30] OECD, 2010
[31] Pérard, 2008
[32] OECD, 2010
[33] Pérard, 2008
[34] Pérard, 2008

resources.[35] As part of the IWRM, the government has engaged citizens and local stakeholders in decision-making processes and in designing water policies. In the water sector, private companies are limited to subcontracting roles to extend water networks and install connections; in the sanitation sector, the private sector accounts for only 13% of infrastructure maintenance and operation, although participation is expected to significantly increase in the coming years.[36] The agency that manages the water sector is working on expanding private participation.

Tunisia's scarce natural water supply has long motivated it to experiment with nonconventional and innovative forms of generating water. For instance, the country has been desalinating brackish and saline water since 1983. In the form of a build-operate-transfer contract in 2008, the government subsidized private investment in a desalination facility, viewing the technology as critical to the country's long-term management strategy.[37] The country also uses artificial groundwater recharge, which is a way to store surplus water from one season for use during dry periods. Also, it has been reusing treated wastewater in agriculture since the 1970s and has one of the highest reuse rates in the world.[38]

While Tunisia's public administration of the water and sewage system are exemplary, the country faces a problem familiar worldwide—under-charging for water services. Water and sanitation tariff structures are applied uniformly across the country instead of reflecting the real economic cost of water across differing regions and the fixed and variable tariff structure—with an emphasis on the variable component—means that 10% of customers pay for more than 80% of the population and 90% of users pay below the real marginal cost.[39]

Jordan has among the lowest amount of water resources per capita in the world. Its resources come primarily from surface and ground water and renewable ground water resources are withdrawn at an unsustainable rate (in 2009, withdrawal rates were up to 20% above the estimated sustainable capacity).[40] Water is also used inefficiently: agriculture uses more than 60% of water resources while contributing only 2.8% to GDP and unaccounted for water reaches 47% in the Amman region (2006 data).[41] "The availability of water varies throughout the country and even residents of Amman receive piped water only once a week."[42] The sector is managed by three authorities (Ministry of Water and Irrigation, Water

[35] The goal of the IWRM is to: 1) achieve more efficient use of water; 2) promote demand management; 3) reform tariffs; 4) encourage public private partnerships; 5) reinforce regulatory frameworks for environmental protection.
[36] OECD, 2010
[37] Louati and Bucknall, 2009
[38] Louati and Bucknall, 2009
[39] This assessment based on 2006 data reported in Pérard, 2008.
[40] Zeitoun, 2009
[41] GTZ, 2006
[42] Zeitoun, 2009

Authority of Jordan, and Jordan Valley Authority) and is very much centralized and politicized. The Minister oversees the "autonomous" agencies so they are not actually independent and regulatory functions are limited to monitoring of the water sector. Additionally, the Ministry of Health is responsible for managing potable water and protecting water quality. The Ministry of Environment is responsible for developing all standards and specifications governing environmental protection, including water resources. The Ministry of Water and Irrigation adopted a national water strategy in 1997 that focused on managing demand and emphasized the role of the private sector in water supply with the goal to improve management efficiency and attract private investment.[43] In 1999 it contracted out the operation and management of water and wastewater services, resulting in significant improvements in supply.

An inefficient pricing policy is one of the main problems with the water sector. The Ministry of Water and Irrigation set a tariff structure that subsidizes the poorest communities, such as small-scale farmers in the Jordan Valley who receive preferential rates. Prices vary based on qualities and uses, where profitable markets such as tourism and industry pay the full cost of water, and higher (and presumably wealthier) consumers pay higher prices to recover the cost of subsidies. In practice, the result of this structure has been prices that are set too low to be sustainable and disparities in price that have average 2001 urban users paying 90 times more than rural users and in some desert areas water is free of charge.[44] Despite its inefficiencies, social and political considerations prevent implementation of reforms to the water pricing structure.[45]

Algeria, the country with the lowest renewable water resources of North Africa, suffers from poor public management and weak incentives to invest in infrastructure. In Algiers, up to 40% of the water carried by the network is lost: 32% due to technical losses and 8% due to illegal consumption.[46] Mediocre agency management has made matters worse. Irregular payments and illegal connections have created a huge backlog of unpaid bills.[47] The National Sanitation Office in 2005 noted that tariffs covered only 10% of operating costs and, as a result, water rationing and shortages are common.[48]

A series of recent reforms may address some of these problems. Water treatment, water supply, and sanitation were managed by four public agencies but in the early 2000's management of the sector was reformed. In 2006, the four agencies were combined under a single agency. A new water law in 2005 emphasized private sector participation to increase efficiency and promote

[43] Wardam, 2004
[44] Pérard, 2008
[45] Wardam, 2004
[46] Pérard, 2008
[47] Global Water Intelligence, 2005a and 2005b
[48] Pérard, 2008

competition, and encouraged the use of concession contracts in public water and sewerage services. The new law installed an independent regulatory agency to oversee the monitoring of water provision and tariff setting.

The 2005 law eliminated the fixed-fee for water system and proposed a new system where people can choose between a high fixed fee or a variable fee based on consumption, as measured by a water meter. The fixed fee is set at such a high level that most consumers would benefit from choosing the variable fee. The aim of this policy is to reduce demand.[49] Tariffs also vary by geography and, in theory, will cover the costs of renovating and expanding potable water infrastructures. The law empowers the government to regulate and enforce water quality and protect areas with vulnerable ecosystems, allowing for penalties for breaking environmental regulations. A greater role for private contractors is also envisioned. Starting in 2005 a contract to manage water and wastewater services for the city of Algiers was awarded, with incentives to upgrade and modernize the water and wastewater utilities to increase reliability and improve service quality to provide water on a 24-hour basis. By 2008, the percent of the population with 24-hour access to quality water increased to 71% from 16% in 2006. Significant progress had also been made in sanitation.[50]

Contrasting the experiences of Tunisia, Algeria, and Jordan points to a maxim that has been understood in the regulation of electric power markets: there is no single best model for reform. In countries where public institutions are well-governed public ownership and management may work adequately—as illustrated in Tunisia. In countries where the public model fails, shifting to private ownership with performance incentives may be necessary, as Algeria and Jordan reveal.[51] All three of these countries have faced severe challenges in getting prices right.

Other countries in the region reveal similar patterns. Egypt has achieved 100% coverage of drinking water supply in urban and rural areas but has been much less successful with wastewater treatment, which covers only 55%, with only 15% coverage in rural areas.[52] Public administration of the water system is highly fragmented, leading to a reorganization that has in theory streamlined the process.[53] But the country still relies heavily on public funds for financing.[54] The government expects that the cost for water services will more than triple over the next 15 years if tariffs are to fully cover financing needs. Yet as of 2006, revenues cover only 40% of costs.[55] Some limited tendering to private companies has begun, such as in New

[49] Pérard, 2008
[50] OECD, 2010
[51] Besant-Jones, 2006
[52] OECD, 2010
[53] Attia, 2004
[54] Pérard, 2008
[55] Pérard, 2008

Cairo where a Spanish company now operates a wastewater treatment plant.[56] Morocco has had similar experiences with tremendous success in providing access to water supply but much less progress in developing wastewater and sewerage systems.[57] Policy reforms in that country have been driven both by the need to develop sustainable financing for new infrastructure but also reducing the financial burden on the poor while expanding service to poor urban and periurban settlements—an extremely difficult task.

China

China's water supply is dominated by two central facts. First is rising demand from rapid growth in industry, urban populations, and agriculture. Second is a highly uneven spatial distribution of water resources—the northern parts of the country are generally arid and the south is much wetter.[58]

As in most countries, total water use in China is dominated by agriculture, which consumes 67% of the country's water while contributing only13.2% to GDP. Water in the North China Plain, where most of the country's important agricultural provinces are located, is supplied by the Haihe, Luanhe, and Yellow Rivers—all now under severe stress leading to over-exploitation of groundwater aquifer resources. Industrial demand accounts for 22% of total demand for water. And as China's economy grows, industrial output is increasingly more profitable than agricultural output, so water resources will increasingly be transferred to industrial purposes.[59]

Several ministries and commissions oversee water management in China. The fragmented nature of water governance, both regionally and nationally, has led to problems such as inefficient and ineffective pricing of urban water, conflicting competencies between government bodies, poor delineation of duties, and a lack of horizontal and vertical coordination.[60] Historically in China, water is viewed as a fundamental public good that should be available to all. Until the last twenty years the price of water within the country was essentially zero.[61] The direct result has been massive inefficiency with few incentives to conserve.

Chinese water management primarily focuses on two major rivers: the northern Yellow River and the southern Yangtze River. Both rivers suffer flood or drought on a regular basis. So water resources management has primarily been supply driven, with an emphasis on large-scale dam building projects and

[56] OECD, 2010
[57] Chauvot de Beauchêne and Mantovani, 2009
[58] Jiang, 2009
[59] Brooks, 2005; World Bank, 1993; Huang et al., 2009
[60] Carmody, 2010
[61] Rong, 2011

agriculture water supply.[62] In the 1990s, as industrial demand rose rapidly, the Yellow River began to regularly run dry leading to increased periods of drought and concerningly low levels of water supply in the north. One direct result of excess water withdrawal and consumption in the basin were the river's increasing cutoff periods from 1972–98. As a worst case, in 1997 there was no discharge at all from the basin to the sea for up to 226 days.[63] These striking facts—a river run dry and polluted—have led to massive reform efforts as well as an outpouring of ideas for improvement management.[64] Those reforms, which have been implemented in highly uneven ways around the country, have led to changes in law as well as pricing and administration.

There are two basic national frameworks for managing water issues. One is the national water law, which was originally introduced in 1988 and updated in 2002. In tandem with that law focused on water pricing and allocation, there are several laws for environmental protection, including several directly relevant to water resource management, for example, *the Law of the People's Republic of China on Prevention and Control of Water Pollution* in 2008.[65] The other main framework is the country's system of national planning, which has been the keystone to most major Chinese efforts to manage depletion and degradation of resources. In the most recent 12th Five-Year Plan (FYP) (end 2010-end 2015), the reduction of water intensity remains the same as the last one at 30 per cent. (The 11th FYP (end 2005-end 2010)'s target was easily surpassed at 37 percent.) The new plan projects that the annual water use will rise to 620 billion cubic meters by 2015. Early last year, the State Council issued *the Opinions of the State Council on Implementing the Strictest Water Resources Management System*,[66] which requires that the national total water usage must be controlled below 700 billion cubic meters in 2030. In 2011, the number was 608 billion cubic meters,[67] which means an approximate annual growth rate of 0.75%. (By contrast, in recent years the annual growth rate of national total water use has been over 1 percent.) So far, climate change has not figured prominently in Chinese water management strategies and there is considerable uncertainty about how altered climates will affect flood, drought and the availability of freshwater resources around the country.[68]

Despite these reforms, much remains to be done. Few of the new laws and formal regulations have been effectively implemented.[69] Leaders have tried to

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[62] Carmody, 2010
[63] Ringler et al., 2010
[64] Jiang, 2009; Cheng and Hu, 2012
[65] For more detailed information, refer to http://chinawaterrisk.org/regulations/water-regulation/ which provides a nice overview on water regulation in China.
[66] Please see at www.china.org.cn/china/2012-02/17/content_24664350.htm
[67] China's National Bureau of Statistics, 2012
[68] Huang et al., 2010; Piao et al. 2010
[69] Huang et al., 2009

encourage water saving technologies since the early 1990s, such as sprinkler systems, drought resistant varieties, and drip irrigation, but adoption rates in northern Chinese villages average less than 20%.[70] Xie (2009) in a World Bank report finds the legal framework still "unsatisfactory." He finds that enforcement is lacking and "the legal framework leaves much room for improvement."[71]

Pricing and Market Reforms

Here we focus on two types of reforms that have been particularly interesting and important.

First have been pricing and market reforms. Water was provided almost free of charge until 1985; since the early 1990s, China has charged for water and has increasingly raised tariffs in both urban and rural areas.[72] Various national policy papers were written in the 1990s that emphasized increasing the water fee. As a result, the total water tariff had an annual growth rate of 16.5% in the 1990s.[73] Based on the National Development and Reform Commission (NDRC) data in 123 cities, water prices and sewage rates are increasing at an annual average rate of 5.49% and 10.63% respectively. In 2006, the NDRC issued regulation suggesting that "the price of water should be based on the cost of supply, including the costs of groundwater or aquifers, constructing pipes and treating sewage."[74] Some provinces and cities in China have taken these ideas to heart and adopted wide-ranging reforms in tariffs, the introduction of limited trading, and new forms of public administration in the water sector.[75]

In addition to pricing reforms there have been three types of market transfers in China. The first type is the transfer of regional water rights. The notable example is the agreement reached in 2000 between Dongyang and Yiwu Counties in Zhejiang Province, which is widely regarded as China's first example of a regional water transfer.[76] In November 2000, Yiwu County paid a lump sum of RMB200 million to Dongyang County for an exchange of 50 million m^3 of water per year from the Hengjin Reservoir in Dongyang County.

The second type is water saving and transferring within a river basin. The Yellow River, for example, as the dominant water source for the populous but water-scarce north, has been at the forefront of innovations in China's water allocation, water regulation and

[70] Huang et al., 2009
[71] Xie, 2009, 43
[72] Xie, 2009
[73] Zhong and Mol, 2010
[74] Carmody, 2010
[75] Zhong and Mol, 2010
[76] Gao, 2006

water transfer/trading. The government—at both the central and local level—has facilitated a series of water-savings transfer projects within large irrigation districts, which transfer water from agriculture users to industrial users with the industries in turn paying the cost of the channel lining and ongoing maintenance. In theory, any enterprise in need of water could submit proposals to the government identifying their water requirements. The successful applicants would be chosen based on the government's development priorities. To date, all such water transfer projects have involved state enterprises, the majority of them from the power industry. Government agencies have been central to the process.

The last type is water transfer within irrigation districts at the farmer level. But the grant of water rights at the farmer level has only occurred to a limited extent to date, principally as part of pilot water efficiency programs in some of the most water-scarce regions. In the pilot districts, water tickets are issued to individual households and may be traded freely among farmers. In practice, however, there have been few instances of trading of water tickets. China's Ministry of Water Resources (MWR) has been working for years towards a rights-based water management system. China's 11th Five-Year Plan (2006–10) specifically requires the establishment of "an initial water right distribution system and a water right transfer system."[77] However, water rights and the rules governing them are not clearly defined yet in China[78]. Earlier drafts of the 2002 Water Law included further provisions regarding the transfer of water rights. However, because the proposal that included these provisions generated much significant controversy, the final version of Water Law does not include the provisions[79].

River Basin Management Reforms

In addition to a shift in pricing, China has also attempted a shift to basin-wide management of water resources. The triggers for these reforms include not just rising demand for water but also the need for upstream–downstream coordination. The shift to decentralized management of water resources and environmental regulation has also created the need for greater coordination at the basin level. Chinese planners have studied lessons from other parts of the world, such as the various river basin management schemes in Mexico[80] and Narmada River Valley in India[81]. Emblematic of the need for reforms is the situation of the drying Yellow river. The basin produced about 14% of Chinese grain harvest and 14% of the country's GDP using only 2% of national water resources.

The 2002 Water Law defined, for the first time, river basin management institutions and functions and strengthens the administrative rights of river basin

[77] State Council of China, 2006
[78] Speed, 2009
[79] Wouters et al., 2004
[80] Mestre R, 2009
[81] Gupta, 2001

management organizations although basin commissions formally predate that law[82]. As of today, China has established river basin management commissions (RBMCs) for its seven large river/lake basins (six river basin management commissions and the Tai Lake Basin Management Agency) as subordinate organizations of the MWR[83]. The RBMCs essentially act as regional offices of MWR and are responsible for cross-province water function zoning plans and undertake a wide array of functions related to withdrawal of water from basins and pollution such as sewage outfalls. In addition, a basin approach to flood management was strengthened in the *1997 Flood Control Law* and a basin approach to water pollution control plans was stated in the *2008 Water Pollution Prevention and Control Law.* Numerous studies, including by Feng (2009) and Shen (2009), have reviewed the experience with these commissions.[84]

As a practical matter, it is hard to see much effect of the RBMCs. The most visible effects are in the Yellow River Conservancy Commission which reacted swiftly to the watershed moment of zero discharge from the Yellow River in 1997. In 1999, the Yellow River Conservancy Commission implemented unified water flow regulation (UWFR) as enforcement of the 1987 cross-provincial water allocation agreement. Implementation of the UWFR contributed to a decline in total irrigation water use in the mid- and downstream areas.[85] The practical effect of this measure, however, stems more from the highly visible impacts of the Yellow River crisis in the country and the attention of central planners to solving the problem.

The impact of RBMCs on other water challenges, such as water quality, is much weaker. China has adopted a system that essentially separates and designates the management of water quantity and water quality to the MWR and MEP, respectively. The MWR is responsible for the water-related environmental management in the water body, while the MEP is responsible for those activities on land. At the river basin level, there is a water resources protection bureau in each river basin commission in China, which is under the leadership of both the MWR and the MEP. Thus, as a matter of theory, water quality issues should be managed in an integrated way. But at the operational level, since each bureau is dependent on different "bosses" for funding, there is little scope for independent action that would allow them to fully integrate their management of water quality in the river basin. In fact, water quality of rivers in eastern China, a populous area subject to the most severe water pollution, is hardly improved in the past decade despite of years of pollution prevention. In China, water quality is broken into five categories that can be described as ''good'' (Classes I, II, and III) or ''poor'' (Classes IV, V, and V beyond which cannot support drinking and swimming). In 2001, only 27% and 39% of Huai River and Hai River's water meet the standard of "good"

[82] Shen, 2003
[83] Rong, 2011
[84] Feng, 2009; Shen, 2009
[85] Ringler et al., 2010

quality[86]; 10 years later, the status quo does not improve much or even slightly worsen with ratios of 38% and 36%[87], respectively.

The United States Southwest

Most of the American West relies heavily on water storage facilities that collect the snow runoffs from the mountains each spring, so not surprisingly the 10 largest dams in the US are all in the West.[88] The US Bureau of Reclamation built most of the water infrastructure in the West to irrigate agriculture and to generate electricity. Groundwater is also an important source in some areas, accounting for 25% of all withdrawals in the 11 western states (as much as 51% in Arizona to as low as 2% in Montana).[89] But in many regions, the withdrawal of groundwater exceeds the natural renewal rate. Irrigation accounts for about 75%-80% of withdrawals in the West, compared to just 34% nationally. [90] Improvements in industrial efficiency over the past two decades have helped to stabilize water usage, but, still, total per capita withdrawal is higher in this region than compared to other regions in the country.[91] During the 1990s, the population in the West grew by almost 20%, with the biggest growth in the most arid states.

Another paper for this conference will look at the Southwestern experience—in particular, the experiences in California—in much more detail.[92] Thus here I will focus briefly on just two aspects of water management in this region. One is the fragmentation of authority, especially as revealed in the management of the Colorado River. The other is the practical impact of market incentives in a system where property rights are not fungible.

States are the primary governing bodies regarding the management of water resources, with each state having different provisions and administrative rules. Federal laws are layered on top. Allocation of water from rivers that run through several states are governed by compacts that states have entered into. For example, New Mexico, Texas, and Colorado have entered a compact on the Rio Grande; Colorado, Nevada, California, Arizona, New Mexico, Utah, and Wyoming have a compact on the Colorado River; and Colorado and Kansas have a compact on the Arkansas River. The US Congress ratifies these compacts and the US Supreme Court has immediate jurisdiction to settle disputes.[93] Additionally, a treaty between the US and Mexico governs the three rivers that those countries share—the Rio Grande, the Colorado and the Tijuana River. As demand for water has risen along with awareness of the various interconnections between surface and

[86] Ministry of Water Resources of People's Republic of China, 2002
[87] Ministry of Water Resources of People's Republic of China, 2012
[88] Tarlock et al., 1998
[89] Kennedy, 2005
[90] Kennedy, 2005; Donohew, 2009
[91] Kennedy, 2005
[92] Barton Thompson, MIT-CSIS Conference paper May 5 2013
[93] Valdes and Maddock, 2010

groundwater systems there has also been rising pressure to manage surface and groundwater uses "conjunctively"—an idea that makes eminent sense yet is extremely difficult to manage in practice. Historically, water rights on the surface and under ground have been assigned in different ways. And some western states, like California and Arizona however, are reluctant to change their groundwater and surface water laws to align with the growing scientific understanding of the physical connection between the two sources.[94] Instead the water law in those two states treats surface water and ground water as separate, where surface water is appropriable but groundwater is not.[95] In addition to the diversity in the assignment of property rights, public administration is also highly fragmented. Often at the state level one department is responsible for surface water, another for groundwater, and still another for hydrology.

The surface water supply system in this region was built mainly from federal funding with the Reclamation Act of 1902 that led to the construction of dams throughout the Southwest. This water supply was intended primarily for agriculture although, over the century, the hydroelectric benefits of large dam projects rose in prominence. The US Bureau of Reclamation (USBR), the principal federal agency responsible for designing and building these dams, entered into contracts with farmers in the region where the dams were being built. The farmers paid the USBR in exchange for guaranteed water at a price level that also covered the cost of the facilities, so in essence, the farmers were paying back the cost of the dam and, when paid off, the farmers would have ownership. In tandem, especially when faced with rising costs, farmers also created irrigation districts to raise money. Today, the USBR controls releases from the reservoirs to the river or stream, the irrigation districts or the state controls diversion from the streams or rivers, and states manage intra-state stream activities.[96] For the American west, the epoch of dam-building and institutional forms that flowed from the need to pay for and manage these infrastructures is now over since building new dams is impractical. (Indeed, a growing number of dams are now slated for removal, although not yet any of the giant western dams.) Today's water management challenges arise in a context where institutions were created to serve earlier functions and must now be adapted to new ones.

One of the most interesting adaptations is the rise of water markets. The western United States began using water markets to reallocate water in the 1980s and its institutional reforms remain ongoing but the development of water markets have been slow to mature.[97] In the US, water for irrigation is still heavily subsidized by the government. For instance, farmers in California's Imperial Irrigation District pay $20 per acre-foot of water while the city of San Diego pays $225 per acre-foot for the same water.[98] These large discrepancies arise, in part, because of the complexity in defining water rights and the huge advantage that incumbents have in shaping the market.[99] The

[94] Valdes and Maddock, 2010
[95] Valdes and Maddock, 2010
[96] Valdes and Maddock, 2010
[97] Donohew, 2009
[98] Murphy, 2003
[99] Donohew, 2009

incumbent's advantage is particularly evident in the doctrine of appropriation, which is the basis for most allocation of surface water in the west. Once water is diverted and right is established, the right to the water remains available to the original and would be off-limits to potential future users.[100] The concept arose in the era of mining—an intense user of water—to prevent new settlers from diverting water upstream of already established settlements further downstream. The effect is to protect senior rights and to create strong incentives for holders of those rights to use water even when other uses might be more efficient. During times of drought, in particular, seniority is important since cutbacks in water favor more senior holders. Other parts of the U.S. use riparian methods for allocating water in which water rights cannot be separated from the land. Under Riparian systems, in times of drought, all users share the same reduced water availability. Large-scale water use that is managed by well-organized interest groups help explain why western states fully or partially embrace the doctrine of prior appropriation. Colorado dropped the riparian system for the prior appropriation system, but California has adopted a hybrid of the two systems.[101]

Thus the basic allocation of water in the southwestern U.S. comes from a series of overlapping institutions. One is the fundamental allocation of private, surface water rights mainly through the doctrine of prior appropriation. Another is the sharing of water resources of the major inter-state river (the Colorado) through a federally managed river compact adopted in 1922. A third is the allocation of those river sources between the U.S. and Mexico. As the demands for water have changed—in particular with the huge surge in demand for water in California—new hybrid markets have emerged on top of these basic institutional arrangements. I illustrate, here, with two examples.

First, along the Colorado River the rising demand for water has forced California to curtail its use and comply with the allocation it received in 1922: 4.4 million acre-feet per year. To do that, a transfer market has emerged that has allowed wealthy cities (e.g., San Diego) to buy water from other regions in California where water is used much less efficiently. A 75 year agreement, currently in its 11th year of operation, allows San Diego to purchase from the Imperial Irrigation District (IID)—a parched agricultural zone located in the desert east of San Diego near the Arizona border—at a cost of $540/acre-foot. The water transfer agreement dictates the kinds of activities that the Imperial Irrigation District must undertake, which include the fallowing of existing cropland and then eventually active conservation measures in the region. In parallel with these programs designed to pare back agricultural uses there is also a program to line two canals to reduce leakage.[102] If a full blown market for water in the Colorado states were created from scratch it is highly unlikely that prices would clear at such high values, but in the hybrid market—where transaction costs for developing trades are high and most existing users face no incentive to trade away their established rights—prices form in quite

[100] Kennedy, 2005
[101] Donohew, 2009
[102] San Diego County Water Authority (2013)

different ways. Ironically, this approach results, most likely, in excessive amounts of technological innovation—San Diego, for example, is building a pioneer desalination plant that probably would be uneconomic if pure market rates for water were prevalent.

Second, very thin hybrid markets are also emerging between the U.S. and Mexico. In the wake of a large 2010 earthquake along the California-Baja border, nearly 400 miles of Mexican canals that normally carry Colorado river water were damaged, leaving Mexico unable to fully use its quota of water. A bilateral agreement between the two countries allows Mexico to store that extra water for three years in Lake Mead while the Mexican authorities repair the canals. Building on that progress, new agreements that might include water quality trading are also taking shape.[103] (And in a sign that policies often have unintended effects, Mexico is also disputing the actions that San Diego is financing to line the U.S. canals to reduce leakage. Before the lining, leaking water in the U.S. flowed into Mexican groundwater and was a major source of water for agricultural operations just over the border in Mexico.)

3: Some Implications for the Future: Integrating Water Management and Improving Water Modeling

To close, we look at two sets of questions. First is what our simple theory of policy change and the illustrative case studies suggests about major reforms to water governance. The ideas for reforms, especially in light of growing concerns about scarcity of water resources, are many. Which of these ideas might actually get adopted? Second we will look at what all this implies for the modeling of water resources and human responses to scarcity.

The Prospects for Institutional Reforms

There are at least four major kinds of pressure for reforms in the allocation and protection of water resources. All have major implications for how water management institutions are organized.

First is Localization. Ivey, Loe, Kreutzwiser, and Ferreyra (2006) examine the influence of existing institutional factors on enhancing or constraining the capacity of local governments to protect source waters, looking specifically at the Oldman River Basin in Alberta.[104] "Source water protection refers to the development and implementation of policies, plans and activities to prevent or minimize direct or indirect release of pollutants into surface or groundwater resources currently used or intended to

[103] Quinlan, 2010

[104] Ivey, Loe, Kreutzwiser, and Ferreyra, 2006

be used in the future as sources of drinking water (O'Connor, 2002; Krewski et al., 2004)."[105] They find that as the trend in governance moves towards devolution, local governments will have to rely on exiting institutional arrangements for land use and water management. In the case of Alberta, the study found that local governments were constrained by the disconnection of land use planning and water management. There was a lack of formal mechanisms in place to allow or encourage local officials to transform knowledge at the municipal level into locally relevant knowledge. Also when the responsibility for regulating intensive livestock operations was assigned to the provincial government where there was an absence of a commitment to source water protection, local actors did not see a role for themselves and therefore their ability to protect source water was constrained. The authors state that in the absence of a commitment to environmental protection by senior levels of government, "strong institutional support to facilitate meaningful and broad public involvement and land and water integration is necessary."

Second is adaptive management. In an adaptive approach, actions are adjusted based on progress toward management objectives.[106] "Implementation of adaptive management approaches has occurred across a spectrum of styles[107], from formal experimental approaches[108] to work that focuses on the role of participation and social learning processes[109]. Although adaptive management is a well-established concept that has received significant theoretical attention, there is limited evidence of its practical effectiveness[110]. Schreiber et al. (2004) listed the vulnerabilities of adaptive management to both scientific limitations and social and institutional constraints.[111] Little information is available to managers on how to undertake adaptive management.[112] In Eberhard et al (2009), the authors focus on providing a "practical approach to guide structured learning in response to uncertainty in knowledge at the catchment scale."[113]

Third is ecosystem services. The central idea here is that natural resources exist not just to serve human needs but also to nourish ecosystems, and in theory it is possible to create markets and other incentives that would encourage those services.[114] A handful of highly successful cases—such as the water protection agreements for the watershed that supplies New York City—suggest that markets for ecosystem services could be very powerful.

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[105] O'Connor, 2002; Krewski et al., 2004
[106] Eberhard et al., 2009
[107] Broderick, 2008
[108] Walters, 1986; Gunderson, 1999
[109] Berkes and Folke, 1998; Pahl-Wostl, 2006
[110] Walters and Holling, 1990; Lee, 1999; Rogers et al., 2000
[111] Schreiber et al., 2004
[112] Allan and Curtis, 2003
[113] Eberhard et al., 2009
[114] Daily, 1997

Fourth is integrated water resources management (IWRM). IWRM has been defined as "*a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*".[115] The central idea behind IWRM is similar to the idea that motivated China to adopt river basin commissions and many other countries to seek similar kinds of reforms. IWRM is intended to bring together different stakeholders, to allow for flexible basin-wide management of water resources, and to incorporate a wide array of ecosystem services as well as human needs in the allocation of water resources.

Evaluating the prospects for these four requires looking at how these ideas might map onto political interests and administrative capabilities that would be needed to put these interesting ideas into practice. Localization maps well, for many political systems are shifting authority to local levels and despite the risk of fragmentation local rule makes it relatively easy for well-organized interests to control outcomes. The other three, however, are much harder to fathom. Adaptive management and ecosystem services have risen in popularity among academics, but they have not been widely enshrined in practice. IWRM is even harder to see implemented because the broad benefits of more coherent management are diffused across stakeholders. There are few interest groups that seek these systems; incumbents, in particular, rarely want the large scale changes that would be entailed in these systems.

Implications for Modeling

Finally, and briefly, I mention some implications for models that might be used to simulate the behavior of water basins and the behavior of the people and firms that utilize those water resources. There is a strong tendency in such modeling to rely on decision-theoretic frameworks that assume optimality. Yet the tenor of the work presented here is that real world outcomes will be structurally biased away from optimal allocation of resources. A new line of research might be opened to explore just how "second best" the real world is likely to be and which kinds of second-best outcomes will be most consequential for certain industries, such as the energy industry.

To get started on such research, here is a short list of standard assumptions that might be varied when building models that allow for more real world portrayal of water-related decision making:

- Differential pricing across sectors of the economy, with early incumbents (e.g., agriculture) enjoying the lowest prices and later entrants (e.g., most of industry, especially new firms) facing higher prices.

[115] Global Water Partnership, 2010

- Persistent use of command and control regulation rather than markets (or social planner perspectives), reflecting the reality that well organized interests often prefer command arrangements that are more readily controlled
- Hybrid markets rather than pure markets in which all trades are fungible. Hybrid markets and thin and marked by high transaction costs.
- A system that self-adjusts not in response to all evidence of scarcity and poor performance—as the advocates of adaptive management argue would be best—but in punctuated form in response to crisis.

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