Thematic Week: Water Economics and Financing

Thematic Axis: Water Markets

Title: Influence of Incentives and Property Rights on Future Water Demand and Disputes

Authors: Peck, Dannele E.[+] and Adams, Richard M.[++]

[+]University of Wyoming, Assistant Professor of Agricultural and Applied Economics, USA.

[++]Oregon State University, Professor Emeritus of Agricultural and Resource Economics, USA

Abstract:

This paper discusses the influence of climate change on future water demand, and the role property rights will play in resolving future water disputes. Climate change is expected to affect water availability through changes in the quantity, variability, timing, intensity, and form of precipitation. This new climatic setting will alter decisions that affect water demand and associated disputes. Climate change will also affect incentives for nations to cooperate over shared water resources. The ability of market institutions to prevent and resolve future disputes will depend on the assignment, enforcement, and trade of well-defined property rights to water resources. Strengths and weaknesses of alternative property rights systems are introduced, followed by a discussion of the unique challenges water presents for the efficient design and allocation of private water rights.

Keywords: incentives, human response, demand, property rights

Introduction

Climate change is expected to affect the quantity, variability, timing, intensity, and form of precipitation. Surface temperatures, evaporation rates, and sea-level are also expected to rise. Water availability will therefore decline in many regions of the world. Reduced water availability and other climate-driven environmental changes, will alter human incentives and decisions related to water use (see Adams and Peck, 2008 for a detailed discussion). The frequency and location of water shortages and disputes around the world will change as a result. Future occurrences and outcomes of water disputes would be relatively easy to anticipate if current patterns of water use and transboundary cooperation remained the same despite climate change. Current water use information could then be combined with predictions of future water supplies to identify areas in which 1) existing water shortages would be worsened and existing disputes exacerbated, and 2) new water shortages and disputes would emerge. In both cases, past observations of cooperation/conflict would suggest future outcomes.

Our ability to anticipate future water disputes is complicated, instead, by the reality that climate change *will* alter patterns of water use and cooperation. Reduced water availability will increase the opportunity cost of current water uses, causing individuals to adjust their quantity and purpose of water use. It will stimulate renewed interest in large-scale water projects, such as reservoirs, pipelines and desalination plants. Reduced water availability will also increase the stakes of water disputes, and thereby alter incentives to honour past water agreements or cooperatively resolve future disputes. In extreme cases, increased water scarcity could cause civil unrest, shifts in political power and changes in the likelihood of transboundary cooperation. The first portion of this paper therefore explores how climate change will directly and indirectly affect water use and disputes.

The second portion of this paper explores how property rights can influence the occurrence and outcome of water disputes. Many water resource disputes are attributable, after all, to either a lack of property rights (resulting in overexploitation of the resource), poorly defined property rights (resulting in third-party costs and benefits), poorly enforced property rights (resulting in under-valuation and diminished trade of water rights), or a change in property rights (resulting in tension between winners and losers). An overview of alternative property rights systems, and their relative strengths and weaknesses is therefore presented, followed by a brief discussion of challenges encountered when applying property rights to water.

Effects of climate change on future water use

We turn our attention first to the effects of decreasing water availability on water use when well-functioning property rights and markets exist. As the supply of water decreases due to climate change, the price of water will rise. The rising price of water will stimulate investment in large-scale water supply projects[1], and induce consumers to decrease water use. These two responses to rising water prices will prevent future shortages from reaching their full, unmitigated potential; however, shortages will nevertheless be more frequent and intense compared to today. Shortages will also be exacerbated by climate-driven increases in water demand. Water is an important input to the production of many goods and services, such as agricultural crops, electricity, and recreation, so climate-driven changes in these markets will have implications for water demand. Some market changes will be directly attributable to reduced water availability. The supply of hydropower, for example, might decrease due to changes in the timing of runoff. The resulting increase in the price of hydropower would cause consumers to seek cheaper sources of energy, the production of which might have different water requirements[2]. Thermoelectric power plants account for 39% of total freshwater withdrawals in the U.S., second only to irrigation (Hutson, et al., 2004), so climate change's impact on energy markets could greatly affect water demand (and water consumption to a lesser extent).

Some climate-driven market changes will not be directly attributable to reduced water availability, but will nevertheless affect water demand. Rising ambient air temperatures, for example, will increase the use of indoor air conditioning, causing demand for electricity, and hence water, to rise. Rising surface temperatures will decrease water quality in aquatic ecosystems; the number of endangered aquatic species (as defined under current statutes) is therefore expected to rise. Governments with legal protection for endangered species may respond by requiring more water allocation to environmental uses, thereby increasing water demand. Some governments may instead relax environmental standards. The frequency and intensity of disputes between water users (e.g. agricultural and environmental) are likely to increase in either case.

Biofuels also demonstrate how changes in a market only indirectly related to water can affect water demand. The rising price of petroleum has stimulated investment in alternative fuel sources, such as biofuels. Emphasis has been placed on biofuels in many countries, in part, because of their perceived (but now contested) potential to reduce greenhouse gas emissions and mitigate climate change. Investment in biofuels has shifted the portfolio of crops grown worldwide away from food crops and towards biofuel feedstocks (e.g. corn and sugar cane). Feedstocks, in some cases, require more water than food crops (Berndes, 2002). Additionally, land that was previously uncultivated (e.g. pastures, grassland, forests) has been converted to cropland in some regions to either grow feedstocks or meet food crop shortages attributable to rising feedstock demand. Increased demand for biofuels could therefore increase demand for water in agriculture. The degree to which feedstocks are expected to create or exacerbate water shortages depends on whether they are grown in regions where water is currently abundant or scarce (de Fraiture, et al., 2008). The spatial pattern of crops grown around the world, and hence agricultural water use, will also change in response to climate-drive changes in growing season length, soil moisture, the occurrence of pests and diseases, and even agricultural policies, such as carbon sequestration incentive programs.

One final climate-driven change that could have important implications for future water demand relates to population and income growth. Although population and income growth will likely continue in the future (causing a steady rightward shift of the demand curve, as illustrated in figure 1b), climate change could alter the rates or patterns of growth (due to water and food shortages, for example), and therefore alter water demand. Similarly, climate change could affect people's choices about where to live, particularly as sea-levels rise and low-lying coastal areas are inundated, causing the spatial distribution of population (and hence water demand) to change (Landis and Reilly, 2006)[3]. If this were to happen on a sufficiently large scale, community characteristics, including leadership and the likelihood of transboundary cooperation, might also shift. Climate-driven changes in demography could therefore have important effects on the occurrence and outcomes of future water disputes.

Our ability to predict future water use depends on our ability to recognize and understand subtle linkages between the market for water and markets for other goods and services. These linkages also provide opportunities to actively influence future water use through market-based incentives and policies, such as taxes and subsidies.[4] Suppose, for example, that individual water users currently use more water than is socially optimal, perhaps because they undervalue future generations. This market failure could be addressed (i.e. water use could be reduced) either directly by imposing a tax on water, or indirectly by taxing goods associated with extensive water-use, such as lawnmowers, electricity, and thirsty crops like alfalfa. Alternatively, subsidies could be placed on goods that help conserve water, such as water-efficient appliances, solar and wind-powered energy, and drought-tolerant plant species for landscaping. Suppose, instead, that housing developers are not currently required to provide a long-term water source for houses they build. In this case, developers do not factor in the cost of providing water, and therefore have no incentive to avoid locations with scarce water. These costs are instead passed on to municipalities, who must find ways to supply additional water, often at a tremendous expense, and more houses are built in water-scarce regions than is socially optimal. This market failure could be corrected by requiring developers to secure long-term water resources for homes they build, or by placing a tax on new houses that covers the cost of providing water. Alternatively, a subsidy could be provided to landowners in water-scarce regions who retire their development rights, or to families who relocate to water-abundant regions. Market-based tools similar to these are already beginning to appear in water-scarce regions of the U.S., such as California and Arizona.

Property rights as a prerequisite to market-based responses and solutions

The above discussion of consumer response to climate-driven changes, and the implications for water-use, relies heavily on the existence of well-functioning markets, and their ability to transmit accurate signals about water's value through prices. In the absence of well-functioning markets, economic theories and tools that involve prices (i.e. much of economics) may seem irrelevant. Recognize, however, that prices can be expressed in any unit of measure, not just money. Regardless of its unit of measure, price simply represents "what must be given up to acquire something." In the presence of markets, climate change will increase the amount of money that must be given up for a unit of water, and hence the amount of other goods that can be purchased. In the absence of markets, the rising price of water might be expressed, instead, as an increase in time required to collect water, or an increase in risk of crop failure and malnutrition.

Regardless of whether markets exist, decreased water availability will require people to sacrifice more to obtain a unit of water—perhaps more money, time, food security, or homeland security. As the opportunity cost of water increases, people will respond by striving to reduce water use (e.g. adjust agricultural practices or crops, reduce livestock numbers), or find new supplies of water (e.g. dig deeper wells, relocate to areas with more water resources). The degree to which individuals can easily reduce their water use differs, however, around the world. The increasing opportunity cost of water in developed countries is expected to cause people to replace lawns with drought tolerant vegetation, or install low-flow toilets and showers. People in developing countries, in contrast, might be forced to reduce their already small crop acreage and subsist on less food, or supplement their dwindling water supply with sources that pose health risks. Even though their opportunity costs are not easily measured in monetary units, they clearly represent the price of reduced water availability.

Regardless of whether formal markets and prices exist, mutually beneficial trade provides a means for individuals to improve their well-being (i.e. net benefit). Trade allows people to specialize in the provision of goods for which their individual skills are most efficient and valuable, and therefore produce a larger quantity of goods for consumption. Mutually beneficial trade can only occur, however, when resource ownership is clearly defined, i.e. when property rights exist. If property rights do not exist, the following two suboptimal outcomes may result, both of which reduce society's well-being: fewer goods will be available for consumption, and individuals who value the goods most will not necessarily get to enjoy them.

To illustrate the former suboptimal outcome, suppose that Person A's skill set is most efficiently applied to extracting groundwater from a deep aquifer, but they cannot prevent others from freely drinking the groundwater they extract, i.e. they do not have, or cannot enforce, a property right to it. In this case, few people would offer their good in exchange for the water, or accept the water in exchange for their good, because they can obtain it for free by simply taking it. In the absence of a property right to the extracted groundwater, Person A has little incentive to continue producing, and soon everyone is worse-off because no water is available for consumption. If, instead, Person A has an enforceable property to the water they extract, people can obtain water only by offering their good in exchange for it. This provides Person A with an incentive to continue producing water, and everyone is better-off because it is available for consumption.

To illustrate the latter suboptimal outcome, suppose that two strangers stumble across an abandoned sprinkler irrigation system at the same time. Both individuals want the irrigation system, but neither has a property right to it, so they argue over who should be allowed to take it. If neither party is willing to concede, the conflict might be resolved through violence. If a local authority intervenes, however, by giving legal ownership to one individual, the second individual can acquire the irrigation system by offering the owner something in exchange for it. If the offer is more valuable to the owner than the irrigation system, an exchange will take place, and both parties will be better-off than before. If the owner values the irrigation system more than the offer, they will instead choose to keep the irrigation system. In either case, the property right results in the transfer of the irrigation system to the person who values it most, rather than the person who is able to intimidate or defeat their competitor.

As the previous stories illustrate, resource disputes or inefficient social outcomes are often attributable to a lack of property rights, or an inability to enforce them. Property rights can therefore play an integral role in resolving water resource disputes. In countries with well-defined and enforced property rights, the first step in resolving a water dispute is to verify which party holds the water right. This step is usually relatively quick and inexpensive because official records are kept and readily available. Once it is clear which party must pay versus be paid for use of a resource, the door to negotiation is opened and a mutually beneficial outcome is possible (Colby, 1998). In situations with poorly defined or enforced rights, negotiation is hindered by disagreements over resource ownership that are more difficult to resolve.

Ownership of water has not yet been legally established in many river basins around the world. Unfortunately, the process of establishing property rights is often lengthy, costly, and subject to disputes between competing parties (Colby, 1998 provides U.S. examples). If legal infrastructure for establishing and enforcing property rights does not exist, and the costs of creating this infrastructure are too large, ownership might be resolved instead, at least temporarily, through force. Unfortunately, as the relative value of water increases, due to decreased availability, the incentive to engage in conflict will also increase (Garfinkel and Skaperdas 2006). Ownership might, alternatively, remain unresolved, in which case competing water users will face incentives to engage in a race to use the resource first. This scenario often results in a “tragedy of the commons” in which water is overexploited and net social benefit is therefore reduced. Unresolved property rights can also lead to negative externalities, a situation in which individuals make water use decisions based on their private benefits and costs, and ignore costs they impose on others. In both situations, individuals’ water use will cause disputes among those who share the resource because their rights and responsibilities are not clearly defined.

Property rights are necessary for market-based solutions to water shortages to emerge and function, including water transfers, tax and subsidy incentive systems, and disaster insurance. Property rights therefore provide a foundation upon which water disputes can be more permanently resolved (Colby, 1998). The first step in designing an efficient property rights system is to determine which type (private, common, or open access) would generate the largest social net benefit in a given scenario (Griffin, 2006). Each system has strengths and weaknesses whose relative magnitudes depend on the nature of the water resource. Private property rights might be the most efficient system for a freshwater spring, for example, but not necessarily for a large aquifer or lake (as discussed later). No property rights system will perform perfectly, however, so some inefficiencies and conflicts will remain regardless of which system is adopted. A brief description of private, common, and open access property rights systems, and their associated strengths and weaknesses, is provided next.

Private property rights are individually owned. They must be completely specified, secure, fully enforceable, and transferable to function efficiently. A strength of private property rights is that they encourage efficient use of water through space and time, as well as private investment in water infrastructure and technology. Because the property right is completely specified, secure and enforceable, the owner exclusively enjoys all the benefits (and pays all the costs) associated with the resource. Their incentive to use and invest in the resource is therefore not perversely influenced by other people’s behaviour. The owner, for example, has no incentive to rely on others to invest in the resource (i.e. free-ride), or race others to use the resource (i.e. tragedy of the commons). Another strength of private property rights is that because they are individually owned, multiple people are no longer allowed to use the same resource, and therefore disputes and costs associated with coordinating individuals’ uses are reduced. Coordination problems might still arise, however, if individual’s property rights are interdependent. In the case of water, for example, one person might hold a right to return flows generated by an upstream use. The interdependence of these two water rights might require the upstream user to coordinate with the downstream user before transferring their right to another owner, location or use, to avoid a dispute.

One important weakness of private property rights is that they can be costly to establish, monitor, enforce, or transfer, depending on the water resource’s characteristics. The property right to a small cistern, for example, may be easy to enforce by building a fence around it, or hiring a guard to monitor it. A large groundwater aquifer or lake, in contrast, may be too costly to fence, too large to patrol, or too difficult to detect when someone other than the owner has extracted water, and therefore too difficult to enforce as a private right. Another potential weakness of a private property right is that it might reduce social benefit by limiting use to a single person. Suppose, for example, that water in a particular river creates a beautiful waterfall. Many people could enjoy the waterfall without diminishing each individual's benefit; therefore, social benefit would be higher if many people were given the right to view the waterfall. Water, in most cases, is a rival good (i.e. one person's use precludes use by others), which implies that it cannot be easily enjoyed by many without significantly decreasing individual users' benefits. This potential weakness of the private property rights system therefore applies infrequently to water.

Common property rights are owned collectively by many people. The primary strength of a common rights system is that it generates higher social net benefit if the resource can be used by many without diminishing individuals' benefits. We have already indicated that this is relatively rare for water resources, however, with the exception of non-consumptive uses. Common property rights also reduce enforcement costs and equity issues because fewer people must be excluded. A weakness of common property rights is that they require the coordination of multiple users, which can be costly and contentious. Multiple users of a groundwater aquifer, for example, might not agree on how, when, where, or by whom the water should be used. Users may have incentives to violate agreed-upon rules of use, so monitoring and enforcement of individuals within the group of owners may still be necessary. Additionally, individuals might have an incentive to free-ride on other group members' resource management investments. If individuals cannot be prevented from enjoying the benefits of others' management activities, then members have no incentive to contribute themselves. A final weakness is that, if a water resource *cannot* be used by multiple people without diminishing individuals' benefits, common property rights might reduce social net benefit. A common right to a unit of irrigation water, for example, cannot be used by one person without preventing someone else's use. If two people attempt to share a unit of water, each individual's portion might not be sufficient to support their crop, in which case social net benefit might be larger if one person is given a private property right instead.

The third type of property right system is open access, a situation in which no property rights are assigned, and hence the resource is available to everyone. The primary strength of open access is that it avoids the costs of establishing, monitoring, coordinating, enforcing, and transferring rights. The critical weakness of open access is that it often provides incentives for people to overexploit the resource (i.e. "tragedy of the commons"), and disputes commonly arise when one party's use negatively affects other parties. Although open access generates costs in the form of socially inefficient water use, the costs of establishing and administering a private or common property rights system (see McCann and Easter, 2004 for discussion of these costs) are sometimes larger. In such cases, open access, although imperfect, may be the most efficient property rights system.

Private property rights are commonly used to administer water resources in the U.S., and are gaining popularity elsewhere, so the benefits of private water rights and water markets are often well known. Difficulties that governments might encounter when applying private property rights to water, a resource with particularly unique and challenging characteristics, should also be recognized. One such characteristic is that the quantity and quality of water are random variables that take on different values through space and time. This makes it difficult to completely specify water rights and to therefore avoid user-interdependencies and externalities. A multi-state water compact along the Colorado River in the western U.S., for example, did not fully specify water rights and responsibilities during times of shortage. Conflicts between states have therefore ensued during the most recent decade of drought (Colby, 1998). Another challenging characteristic is that water resources are dispersed widely and dynamically through both space and time. It is therefore costly to monitor water availability and use, and enforce individual rights. An intricate and costly system of gauges on streams, canals, and groundwater pumps is often needed to accurately monitor and enforce withdrawals.

Further complicating private property rights to water resources is that only a portion of water withdrawn is actually consumed, with the rest often returning to streams and aquifers. Opportunities therefore exist for two or more water users to benefit from (and hold water rights to) the same drop of water at different points in time. A large portion of water withdrawn for irrigation, for example, returns to streams and canals, and becomes available to downstream users. While it would be inefficient for this water to go unused, allocating a separate water right to it creates interdependencies between users. Such interdependencies encumber efforts to buy and sell water rights, because changes to the type, location, or timing of use might injure downstream users that hold rights to return flows. Interdependencies therefore require the coordination of private property rights, which can be costly, and can also decrease the volume and value of tradable water rights. One final challenging characteristic of water is that it is difficult to physically store and move without costly infrastructure. The spatial scale of trade in a water market is therefore often limited.

If a community that previously allocated water through open access determines that a private property rights system would increase social net benefit, they must then decide how to initially allocate private water rights among users. The Coase Theorem in economics states that, in the absence of barriers to negotiation and trade (such as high transaction costs or an unwillingness to negotiate), the initial allocation of property rights will influence neither the final distribution of water rights among parties, nor the resulting social net benefit (see Griffin, 2006 for more details). If negotiation is free, it does not matter (from an efficiency standpoint) to whom the property rights are initially assigned.[5]

Negotiation is rarely free, however, in which case the initial allocation of water rights has important implications for water use and resulting social net benefits. In such cases, rights should be allocated carefully. Suppose that the property right to an aquifer must be given to a single party or individual, rather than being divided among parties, and that subsequent negotiation between parties will not be possible. A decision maker can determine the most efficient initial allocation of water rights in this scenario by answering the following series of questions. "If the right is given to party A, how will they use the water, and how large will the associated social net benefit of their use be? If instead the right is given to party B, how will they use the water, and how large will the associated social net benefit of their use be? Which party's use generates the largest net social benefit?" The party whose use would generate the largest social net benefit should be given the water right. Although this decision framework clearly abstracts from real-world complications, it provides a framework for understanding the basic nature of the problem.

While this process helps identify the property rights allocation that increases society's net benefits, it does not consider the distribution of net benefit among members of society. Distribution or redistribution of property rights will generate winners and losers (and will therefore be contentious). Parties who lose wealth under the new distribution of property rights will contest the decision even though it is socially efficient. One means of addressing this is to require winners to compensate losers. However, winners would benefit more if they were not required to compensate the losers, and therefore may be unhappy with that arrangement. In the world of resource allocation, no property rights system can completely eliminate conflict. The challenge is therefore to understand disputes that are likely to arise under alternative property rights systems, and under alternative allocations of property rights, and choose the system that finds a desirable balance between social net benefit and equity.

Despite the challenges of defining and enforcing property rights, they do make negotiation possible, and hence the peaceful resolution of water disputes as well. Since negotiation is critical for trade to occur, property rights are also a prerequisite for a wide variety of market-based tools that can be used to alleviate water shortages and prevent or resolve water conflicts. Water purchases, leases, option contracts, and banks, for example, function efficiently only if ownership of water resources is defined relatively clearly and completely. Investment in the development of new technologies to enhance water supplies or reduce water demand will be more intense and efficient if intellectual property rights are enforced. New water-conserving technologies and practices will be adopted more readily if water users are allowed to keep and sell the property right to conserved water. Similarly, landowners and homeowners will invest more in water-conserving technology if the property right to their land and home is secure, i.e. cannot be easily taken away. These same individuals will also invest more in water-related risk management tools, such as insurance (see Leiva and Skees, 2005 for an example), if their property rights make both their responsibilities clear (e.g. whether they have the responsibility to manage risk and mitigate disasters on their own or the right to receive disaster assistance from the government). Even supply-side solutions, such as new reservoirs, pipelines and desalination plants, reduce conflicts only if existing users' property rights to land and water are well-documented, monitored, and enforced. Because property rights are critical for the success of market-based tools, it is important to understand how their characteristics influence not only the occurrence of water conflicts, but also the subset of feasible conflict resolution tools.

Summary

The occurrences and outcomes of future water disputes will not only be directly influenced by climate-driven changes in water supply, but also by people's responses to climate change, which will impact water demand. Decreased water availability will increase the opportunity cost of water and therefore decrease per capita water use. However, other climate-driven changes will cause water use to increase. In many cases, changes in markets that are only indirectly related to water will have significant implications for water use. Whether climate change will cause future per capita water use to increase or decrease depends on the relative magnitude of changes in supply and demand. If future water use increases, disputes are likely to increase as well, not only in areas where water is already scarce, but also in areas where water is currently abundant but expected to become scarce due to climate change.

Property rights, when established and enforced, facilitate the negotiation of mutually beneficial outcomes. When property rights are not established or enforced, it is difficult to resolve conflict. Establishing rights can be costly, however, and no property rights system can eliminate all inefficiencies or resolve all disputes. It is important, therefore, to consider the relative strengths and weaknesses of alternative property rights systems, including open access, for each unique water resource situation. Depending on characteristics of the water resource and the involved parties, one system might perform more efficiently than the others.

If private property rights are the most efficient option, administrators should expect water's unique characteristics to generate challenges, such as interdependence between individuals with private water rights, and costly monitoring of water use and availability. The most difficult challenge, perhaps, is deciding how to allocate water rights among users when negotiation is costly or difficult. The allocation that maximizes social net benefit may not be equitable. Despite the challenges and shortcomings, well-defined and enforced property rights are necessary for negotiation to be a viable tool for resolving conflict, and for market-based tools to function effectively and efficiently.

Bibliography

Adams, R. and Peck, D., 2008. Effects of climate change on drought frequency: potential impacts and mitigation opportunities, *in* Dinar, A. and Garrido, A. (eds.), Managing water resources in a time of global change: mountains, valleys and flood plains.

Berndes, G., 2002. Bioenergy and water – the implications of large-scale bioenergy production for water use and supply, Global Environmental Change, 12, pp: 253-271.

Colby, B., 1998. Negotiated transactions as conflict resolution mechanisms: water bargaining in the U.S. West, *in* Easter, K.; Rosegrant, M. and Dinar A. (eds.), Markets for water: potential and performance.

de Fraiture, C.; Giordano, M. and Liao, Y., 2008. Biofuels and implications for agricultural water use: blue impacts of green energy, Water Policy, 10 Supplement 1, pp: 67-81.

Garfinkel, M. and Skaperdas, S., 2006. Economics of conflict: an overview, *in* Sandler, T. and Hartley, K. (eds.), Handbook of Defense Economics, vol. 2.

Griffin, R., 2006. Water resource economics: the analysis of scarcity, policies, and projects, 402pp.

Hutson, S.; Barber, N.; Kenny, J.; Linsey, K.; Lumia, D. and Maupin, M., 2004. Estimated use of water in the United States in 2000, Circular 1268, U.S. Geological Survey. Available: http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf

Landis, J. and Reilly, M., 2006. Urbanization scenarios, *in* Smith, J. and Mendelsohn, R. (eds.), The impact of climate change on regional systems: a comprehensive analysis of California.

Leiva, A. and Skees, J., 2005. Managing irrigation risk with inflow-based derivatives: the case of Rio Mayo Irrigation District in Sonora, Mexico, Selected paper at the American Agricultural Economics Association Annual Meeting. Available: http://ageconsearch.umn.edu/bitstream/19448/1/sp05le05.pdf.

McCann, L. and Easter, K., 2004. A framework for estimating the transaction costs of alternative mechanisms for water exchange and allocation, Water Resources Research, 40, W09S09, doi: 10.1029/2003WR002830.

<u>Footnotes</u>

[1] Supply-side responses to climate change will not be sufficient to completely mitigate future water shortages and disputes. Demand-side responses to climate change and associated policies will play an equally, if not more important role, and are therefore the focus of this paper.

[2] Alternative sources of energy might also have different effects on water quality, with direct implications for water supply.

[3] This could have additional implications for water use through its affect on land-use patterns. As coastal populations migrate inland, for example, they might displace agricultural land-use, or encourage the development of agriculture in new areas.

[4] Care should be taken, however, to only impose policies when a market failure, such as an externality or public good, exists. Otherwise, policies may generate unexpected consequences that could make society worse off.

[5] Note, however, that the initial allocation of property rights will affect the final distribution of *wealth* among parties. Initial allocation of property rights therefore often requires decision makers to make trade-offs between efficiency and equity.