ISSUE BRIEF

Pre-Positioned Policy as Public Adaptation to Climate Change

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RESOURCES FOR THE FUTURE

June 2010
Issue Brief 10-07

Resources for the Future

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Pre-Positioned Policy as Public Adaptation to Climate Change

V. Kerry Smith[1]

As defined by the Intergovernmental Panel on Climate Change, adaptation includes a set of actions to moderate harm or exploit beneficial opportunities in response to climate change. To date, little research has addressed public policy options to frame the nation's approach to adapt to a changing climate. In light of scientific evidence of extreme and unpredictable climate change, prudent policy requires consideration of what to do if markets and people fail to anticipate these changes, or are constrained in their ability to react. This issue brief is one in a series that results from the second phase of a domestic adaptation research project conducted by Resources for the Future. The briefs are primarily intended for use by decisionmakers in confronting the complex and difficult task of effectively adapting the United States to climate change impacts, but may also offer insight and value to scholars and the general public. This research was supported by a grant from the Smith-Richardson Foundation.

Policy Recommendations

Most discussions of policies for climate adaptation have focused on augmenting the capacity of natural and/or manmade systems to provide the services that are reduced or made more variable because of climate change. This orientation presumes those in charge can "guess" what is best in advance and know exactly where each unit of added capacity will be needed. Alternatively, policy could rely on developing mechanisms that give people and firms incentives to respond on their own to changes in the services provided by the climate system. These strategies could be

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designed in advance and create pre-positioned, incentive-based policies. In developing these alternatives, several issues need to be distinguished.

INCENTIVE-BASED POLICIES

Substitutes. Where adaptation involves substitute resources for the services of the climate system, such as electricity for cooling and water to compensate for reduced precipitation, real-time pricing and other systems that allow prices to reflect the varying costs of these services, can be used to provide incentives that are consistent with the real costs of providing these services under the new conditions. These systems can also balance conservation and revenue needs. In some situations they will have a further benefit by providing incentives for adopting technologies that would mitigate climate change.

Complements. Where climate change alters environmental services that are complementary to private goods, such as time allocated to outdoor recreation, incentive-based policies should focus on rationing schemes for access to the complementary goods and services whose values are related to climate services. For example, a change in the timing and extent of snow pack could alter skiing conditions –leading to a bunching of demand under ideal weather conditions[2]. This is a situation where a mix of innovative pricing or non-price rationing policies would enhance the utilization of resources affected by the new snow conditions as well as the overall experiences of those using them.

CAPACITY INVESTMENTS

Conventional economic analysis of choice between a price versus a quantity instrument under uncertainty is not relevant to the evaluation of capacity additions intended to “replace” or augment climate services. In this case the capacity additions cannot be assumed to provide an assured increase in the supply of environmental services that have been reduced by climate change.

By contrast, varying the pricing of the services with large differences in the incremental costs of services over time, space, or with variations in predictable environmental conditions, alters the demands for these services and reduces the disparities in the losses resulting from climate change.

INFORMATION AND VOLUNTARY PROGRAMS

The road to doom is paved with good intentions. Information alone does not guarantee the desired response. Information programs must recognize that there is growing competition for consumers’ attention and any response to new information is not immediate. It requires effort and sometimes new expenditures on the part of households or firms. Collective responses to

[2] See for example Bustic et al. (2008).

public announcements, such as evacuations, need to consider the consequences of the scale of action that they assume will be needed.

Voluntary programs can work, but they should be designed based on a logic that assumes a small number of people will respond and others will “free ride” if they can.

TIMING

For electricity, federal mandates already call for encouraging demand-response policies. In the case of water, mandates are increasing for incentive-based conservation programs. These requirements reinforce the prospect for motivating the dynamic pricing logic as a form of pre-positioned, incentive-based adaptation. Policy needs to be designed to signal changes in pricing of resources during times of extreme climatic conditions so that households and firms have the opportunity to change commitments to patterns of resource use that presume a stable set of climate services.

Background

Adaptations motivated by climate change are actions that modify public or private resource allocations to adjust for changes in the services provided by the climate system. Using irrigation in lieu of rainfall to maintain agricultural output and air conditioning to offset higher temperatures that would impinge on health are examples where substitutions for natural resources reduce the effects of climate-related changes in weather patterns. Actions such as these allow activities to continue at levels comparable to those before the change in natural conditions, although costs may be higher. Adaptation can also reduce the long-term impact of extreme events, such as hurricanes, through improved warnings and evacuation procedures as well as modifications in emergency response activities. To be “pre-positioned,” these adaptation mechanisms must be deployable in advance and modified easily in response to changes in the amounts or pattern of variability in the environmental services that people anticipate from the climate system.

The design of adaptation policy needs to take into account how actions responding to climate change affect the goods and services people want. The motivations for substituting private services to compensate for unfavorable changes in temperature or water availability are different from the motivations for changing the use of complementary activities that have greater economic worth when weather conditions are favorable.

Motivation

Uncertainty is a fact of life. People and institutions adjust in a variety of ways to its implications. To assure a reliable supply of electricity, power companies maintain excess capacity, participate in spot and forward wholesale markets to contract for power, or both. Private insurance allows people and firms to develop planned responses to the effects of low-probability events. Large, complex economies offer an array of these types of options precisely because people want to convert the unpredictable to predictable. The proposal to consider pre-positioned policy as adaptation recognizes that the set of currently available adjustment options may need to change to meet new types of uncertainties. Moreover, in cases where environmental services are not closely related to marketed private goods, the responses may need to be completely new.

Temperature and precipitation changes will vary over time and space, affecting aquatic and terrestrial ecosystems as well as the people who depend on their services. Climate change is also expected to increase the severity of storms, sea-level rise, and the impact of both on coastal resources. Policies need to be tailored to each type of change, engaging different mixes of private and public resources.

Incentive-Based Policy

SUBSTITUTES

Changes in temperature and precipitation will alter demands for electricity and water. Currently, electricity and water systems provide the means to partially substitute for changes in natural conditions as well as collect a fee for use of the resource. The most direct type of adaptation would be incentive based, such as changes in pricing electricity and water. Evaluations of any new pricing policies need to consider their welfare effects, implications for conservation, and other effects that influence their acceptability, such as the effects on the total revenue these commodities provide to those entities that are responsible for providing them.

In the case of electricity, most residential customers face constant price (or a constant price schedule) regardless of the wholesale demand supply balance. This practice cannot be justified on efficiency grounds. Moreover, the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 call for greater attention to demand-response policies and alternative forms of real-time pricing that signal the changing incremental costs of power every hour.

In addition to being more efficient than constant price schedules, real-time pricing (RTP) programs are incentive-based adaptation policies for climate change. RTP programs establish pricing rules that can signal changes in energy costs in close correspondence to real time.[3] The rules for how these price changes are given vary with the design of each program. Table 1 describes some of the most commonly used programs. Figure 1 displays the effects of conventional rates and RTP, as well as time-of-use electricity rates[4] and critical peak prices (CPP) that contract for prices reflecting wholesale rates (with advanced notice) during a fixed number of critical hours.

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[3] At a general level, they are a form of nonlinear prices.

[4] Time-of-use electricity rates do not reflect dynamic pricing because they are not dispatched based on changes in the wholesale prices over time with the balance of varying demands and supplies of electricity.

Each pricing scheme is a hedging contract that enlists customers' participation in pricing rules that allow them to share the risks posed by the uncertainty in what the costs of service will be when it is needed (due to wholesale price variability). Each price contract offers a trade-off between price volatility and price level. Flat rates (or fixed price schedules regardless of costs when the services are provided) impose all the price uncertainty on the suppliers of products who assure the availability of these services under specified reliability terms. As prices become more dynamic, the hedging premium implicit in price contracts decreases. At the same time, however, the signals about the costs of providing service become clearer, and as a result there are more direct incentives given to households and firms to economize.

Table 1: Definitions of Alternative Demand Response Policies

<table>
<tr><th colspan="2">Demand Response Options</th></tr>
<tr><th>Price-Based Options</th><th>Incentive-Based Programs</th></tr>
<tr>
<td>• Time-of-use (TOU): a rate with different unit prices for usage during different blocks of time, usually defined for a 24 hour day. TOU rates reflect the average cost of generating and delivering power during those time periods.
• Real-time pricing (RTP): a rate in which the price for electricity typically fluctuates hourly reflecting changes in the wholesale price of electricity. Customers are typically notified of RTP prices on a day-ahead or hour-ahead basis.
• Critical Peak Pricing (CPP): CPP rates are a hybrid of the TOU and RTP design. The basic rate structure is TOU. However, provision is made for replacing the normal peak price with a much higher CPP event price under specified trigger conditions (e.g., when system reliability is compromised or supply prices are very high).</td>
<td>• Direct load control: a program by which the program operator remotely shuts down or cycles a customer's electrical equipment (e.g. air conditioner, water heater) on short notice. Direct load control programs are primarily offered to residential or small commercial customers.
• Interruptible/curtailable (I/C) service: curtailment options integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties maybe assessed for failure to curtail. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers.
• Demand Bidding/Buyback Programs: customers offer bids to curtail based on wholesale electricity market prices or an equivalent. Mainly offered to large customers (e.g., one megawatt [MW] and over).
• Emergency Demand Response Programs: programs that provide incentive payments to customers for load reductions during periods when reserve shortfalls arise.
• Capacity Market Programs: customers offer load curtailments as system capacity to replace conventional generation or delivery resources. Customers typically receive day-of notice of events. Incentives usually consist of up-front reservation payments, and face penalties for failure to curtail when called upon to do so.
• Ancillary Services Market Programs: customers bid load curtailments in ISO/RTO markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. If their load curtailments are needed, they are called by the ISO/RTO, and may be paid the spot market energy price.</td>
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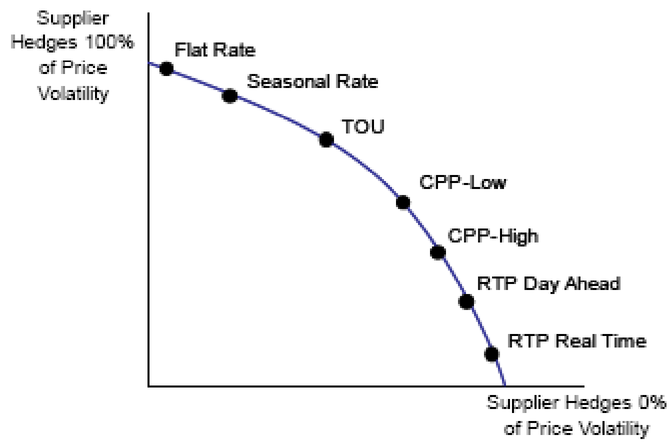
Source: U.S. Department of Energy. 2006, xii.

Figure 1: Hedging Risk of Price Variability



Notes: TOU=time of use; CPP=critical peak pricing; RTP=real-time pricing.
Source: Faruqui and Woods 2008

These types of price contracts could also offer cash rebates for load reductions from pre-defined baseline loads at specified times. Defining the baseline from which these reductions would take place, assuring compliance with the contracts, and financing rebates are all issues with this approach. Nonetheless, at the conceptual level, both RTP and real-time demand-reduction programs can be designed to substitute for adding capacity to meet peak demands for time varying services.[5]

To the extent that temperature change alters the time profile of electricity demand, any policy that more accurately conveys the incremental costs of substitute cooling services to consumers will encourage more efficient adaptation. It will also create long-term incentives to find the most effective substitution options. Thus, changes in policy to some form of RTP that can be modified as the temporal pattern of electricity demand changes, is pre-positioned adaptation. It signals the new variability in costs due to climate change to consumers.

Efficiency is laudable (especially to economists), but performance in influencing peak demand, as a form of conservation, and the effects of these pricing contracts on provider revenues are also important. More than 70 U.S. utilities have offered voluntary RTP tariff schedules on either a pilot

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[5] Most analysis of price stabilization policy begins with Waugh's (1944) early discussion. As Newberry and Stiglitz (1981) note, this type of analysis relies on linear demand-and-supply schedules for market goods, instantaneous responses to changes in market prices, additive disturbances, and a price stabilized at the mean of the prices that would have prevailed in a market without prices stabilized. Recent work has demonstrated how price caps break down in the presence of demand uncertainty. Earle et al. (2007), for example, demonstrate that in contrast to the case where a future realization of demand is known, price caps under demand uncertainty that are close to marginal cost will not maximize welfare. This result suggests that incentive-based policies intended to encourage efficient use of resources that substitute for the services provided by the climate system will need to signal how the incremental costs of these services change with demand.

or permanent basis.[6] Some lessons have emerged that are relevant to using dynamic pricing as a climate adaptation policy.

First, customers must have access to automated metering infrastructure and a link to a smart thermostat or home area network. Energy orbs or systems that readily inform customers of real-time changes in the incremental costs of service and allow them to make automatic responses to these changes are essential to creating effective links and the means for users to respond to the signals they are given. They allow coordination of incentives and responses in ways that match the provision patterns of the service. A synthesized summary of 15 experiments confirms this intuition and suggests that responses to CPP are twice as large (36 percent versus 17 percent) when customers have technology allowing them to know and adapt to prices.[7] For such systems to work, customers also must know and understand the incentive structures and the opportunities to respond to them.[8]

Second, in most situations, these pricing contracts are not compulsory. Their efficacy is enhanced when participation incentives align with the incremental costs customers face in responding to new pricing contracts. To accomplish this, the information about the pricing systems must be clear and understandable. Marketing programs that recognize customers are heterogeneous are important tools. Therefore, programs need to prioritize efforts in recruiting participants based on customers' abilities to respond with lowered usage to changes in the costs during the periods of peak demand.

Third, demand-response policies are substitutes for capacity. However, returns to demand-response programs in this role can diminish, as the reliance on them increases for a given system and the extent of the demand-response levels increase. In effect, as more customers get involved, the system "uses up" decentralized conservation as a substitute for new capacity. These diminishing returns will depend on the quality of the estimates of price responsiveness for the classes of customers participating.[9]

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[6] Barbose et al. (2004) provide a detailed early review of electric utilities' experience with real-time pricing policies. More recent updates by the U.S. Department of Energy (2006) and Faruqui and Wood (2008) focus on the theoretical potential for dynamic pricing and give more limited attention to the issue of recruiting customers to accept these systems. The Faruqui-Wood analysis does highlight the importance of customers' access to the technology that lets them know usage and respond to pricing changes. The recent Federal Energy Regulatory Commission (2009) assessment is largely a simulation analysis that considers ideal performance. Borenstein et al. (2002) offers an excellent overview of the economic issues for real-time pricing.

[7] See Faruqui and Sergici 2009.

[8] A variety of methods allow customers to monitor energy use and program thermostats or other devices to respond to signals from an electricity provider. An energy orb is a simple visual (sometimes color coded) for participating demand-response customers to conserve their power usage. Some technology providers are offering system based or "swarm logic" to allow a wireless control unit that learns power cycles of appliances and reconfigures them to maximize collective efficiency (see Hamilton 2009 for a summary).

[9] Earle et al. (2009) explain this point based on the reliability of demand response as a substitute for capacity. Holding the loss-of-load expectation constant, they compare the effective level of carrying capacity with the actual amount of enrolled

When one considers the record for rebates and real-time demand-reduction programs, the properties ascribed to the ideal versions of these systems are difficult to realize. They are sensitive to the definition of the baseline and a rebate set in advance (before costs are known).[10] When they are voluntary, these programs can induce the wrong customers to participate, so the demand response realized is conservation that would have happened without the program. Moral hazard can arise if customer behavior can affect the baseline used in measuring energy saving.

In general, pricing policies are preferred to rebates for quantity reductions. These policies provide all the information that improves the reliability of predictions for the demand response to dynamic prices and address the potential provider revenue uncertainties.

Moving to dynamic pricing systems has important potential benefits. RTP can change the private incentives for decentralized renewable energy systems for some users. The value of solar power (photovoltaic systems) increases in some areas of the country (i.e., California and Arizona) by as much as 50 percent. In this case, an incentive-based policy offers greater opportunities than a predefined capacity addition to a hydro system to adapt efficiently to changing climate and promote the adoption of mitigating technologies that can reduce carbon footprints.[11]

In the case of water, hourly prices make little sense. The incremental costs of delivering water vary seasonally and pricing policies should be designed to reflect the differences in incremental costs of service. Based on the limited evidence available to us, seasonal prices and prices that adapt to future precipitation forecasts might make more sense. These types of incentive structures create consumer expectations that the costs for service will depend on natural conditions. While there have been no formal evaluations of these types of systems, consumers do respond to prices differently based on local weather conditions. Table 2 provides one example for residential water use in Phoenix, Arizona that distinguishes the size of the customer and the timing of the demand by season.

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capacity. Their simulation is exceptionally favorable to a demand-response program and reflects the importance of the size of any single source of capacity in meeting the peak. However, if they altered their model and allowed different structures of response for different classes of customers, the results suggesting diminishing returns would have been more nuanced and dependent on the heterogeneity of the customer base in terms of the distribution of demand responses for different classes of customers.

[10] Wolak's (2006) analysis of the CPP experiment for a small number of residential customers of the City of Anaheim Public Utilities found customers with the pricing program used 12 percent less electricity during peak hours of the day on CPP days compared to the control. However, the consumption redactors paid rebates during CPP days provide strong support for an overly generous method for setting the baseline for refunds. This funding supports the need to consider setting baselines for any more general real-time demand-reduction programs based on pre-purchases for customers to reduce usage.

[11] See Borenstein (2005) for further discussion of this result.

Table 2: Water Demand and Weather for Phoenix Residential Customers

Panel A

Price elasticity of demand[b]				
Percentile	Normal year[c]	Dry year[d]	Normal minimum water use	Dry minimum water use
10%	-.966	-.202	6.04	6.22
25%	-.471	-.143	9.83	10.67
50%	-.205	-.099	15.61	15.92
75%	-.079	-.003	23.44	23.95
90%	-.081	**	32.98	33.71

Panel B

Weather variables				
	Normal year		Dry year	
Temperature	Minimum use	Maximum use	Minimum use	Maximum use
Low	36.5	83.9	38.8	84.8
Precipitation				
Average	0.61		0.30	
Precipitation days (average)	3.18		1.78	

Source: Klaiber et al. 2009.

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[b] Measures the percentage change in the quantity threshold defining point, where 10, 25, 50, 75, and 90 percent of customers have lower demand in response to change in marginal price.
[c] Based on differences in demand for corresponding months in 2001–1999.
[d] Based on differences in demand for corresponding months in 2002–2000.

The first two columns in Panel A of the table, report the estimates of the residential price elasticity of demand for water using matched months from two years when customers experienced a change in their marginal price schedules. The customers used to construct the summaries remained in the same block of the systems' increasing block water pricing schedule. The marginal price per unit of water for each of these months changes for these years. The next two columns describe the patterns of water usage (minimum and maximum usage) for customers in the years associated with the elasticity estimates. Price elasticities measure the responses of the quantity to the changes in the price at each percentile usage level from 10–90 percent. These results allow an assessment of three aspects of water demand.

First, price is more inelastic at higher levels of use. As a result, large users adapted little to price changes while those with smaller usage levels also had inelastic demands (i.e., price elasticities implying a less-than-equal percentage decline in water used for the percentage increase in price) but they are larger in absolute magnitude and thus imply larger responses. These results suggest that different pricing policies for larger and smaller customers can balance the objectives of conservation and revenue neutrality. Second, it is possible to avoid complex economic models of how consumers respond to increasing block pricing structures by exploiting changes in the schedules over time. The Phoenix water-pricing system has an increasing block-rate structure with a small unit price for the initial block and then a higher one for a second block. This analysis exploits the changes in the marginal prices in winter and summer and the fact that the provider increased these rates over the years studied. Moreover, the differences between winter and summer phased in and out gradually. Thus it was possible to estimate price responsiveness without considering the implications of the full price schedule. Finally, as Panel B illustrates, precipitation patterns were different in the years where data on consumption were available.

To confirm the effect of weather (i.e., precipitation) on water demand, consider the two sets of elasticity estimates.[12] The first corresponds to a "normal" year and the second, a "dry" year. The estimates indicate how customers' responsiveness to the price changes varies with differences in seasonal precipitation. As we might expect, these residential customers were more responsive to price changes in normal conditions and less when it was dry. Thus, under dry conditions, price changes must be larger to realize the same reduction of water use that might be needed for a given level of conservation. This leads to a second point: dynamic pricing in this case should adapt

[12] These results are based on models developed for changes in the consumption levels defining the percentiles for water consumption by residential customers for census block groups. The analysis treats the periodic increases in marginal prices for water in different months as a quasi-random experiment. All but the 10 percentile customers remain in their consumption block, so the price changes are exogenous. Analysis of the year-to-year change in monthly water consumption for specific percentiles (computed for census block groups) as the marginal price increased allows control for households' demographic characteristics and permits the price change to be treated as exogenous. See Klaiber et al. 2009 for further discussion.

the differential between seasonal rates *with weather forecasts.*[13] Offering these rate schedules to different classes of customers changes the nature of the incentives for augmenting household water saving, depending on local conditions as well as the size and temporal structure of price differences.

Third, the elasticity measures indicate that households are different. As a result, balancing efficiency, conservation, and revenue neutrality need not depend on one dynamic price system for all customers. In the case of electricity and water, the opportunities to take advantage of heterogeneity in customers are especially important. Of course, for these systems to be effective, customers must have the ability to monitor their usage so they respond as they learn how their consumption affects their costs under these new pricing policies.[14]

As electricity and water systems experience more stress from impacts of climate change, policies such as dynamic pricing will allow consumers to more effectively adapt to changing costs of serving them. Similarly, extreme climate impacts may necessitate the development of pre-positioned substitutes for existing policies that were written under historical climate conditions.[15] Under previous climate regimes, federal and state governments in many cases were able to respond to extreme events effectively enough to maintain public services and social continuity. Future extreme disasters related to climate change may fall outside the traditional reference window on which policies were designed, which may result in an inability of local and state governments to respond to these emergency events.[16]

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[13] An example of this practice is readily found in economic models of the effects of temperature and precipitation on agricultural yields (see Schlenker et al. 2005 for examples). In the case of other commodity demands, Planalytics contends that weather patterns drive consumer demand and can be used to improve forecasting. Among their promotional materials is a case study of Nestlé Waters North America's use of weather forecasts to improve forecasts of bottled water demand in summer months (see www.planalytics.com/Content196.phtml for other this and other examples, accessed July 30, 2009).

[14] Kenny et al. (2008) found that access to smart-metering technology affected water demand in Aurora, Colorado. Unfortunately, the design of the system implied that the effect of information in enhancing conservation incentives could not be separately measured. Those consumers with large water usage had greater incentives to purchase the meters, so the results implied a positive relationship between usage and smart meters. The decision on meters was endogenous and reflects the influence of large users.

[15] Other issue briefs in this series extensively address potential policy reforms that may assist adaptation in natural and human systems (see Smith and Travis 2010; Farber 2009), so this essay will not cover that well-trod ground. Rather, it may prove advantageous for the federal government to design and implement policies that are written not to enter into effect until some kind of pre-established threshold is reached.

[16] Hurricane Katrina represents a useful illustration of this shifting dynamic of policy-event interactions. In his issue brief, Landy (2010) proposes a pre-positioned policy that would give the president the authority to appoint an officer in charge for the recovery from a specific extreme event. The officer in charge would coordinate federal agency responses, convene necessary state- and regional-response entities, and control some funds to be used for recovery purposes. This policy, effective only after an event is declared an official megadisaster, would be employed as a substitute for current disaster-response policies, which proved ineffective in responding the challenges of Hurricane Katrina. Similarly flexible and innovative policies deserve more extensive consideration from policymakers.

COMPLEMENTS

The services people experience from aquatic and terrestrial ecosystems fall into two categories: those serving as complements to the time, and other goods people use in recreational pursuits, and those that underpin everyday processes of natural systems. When asked about these latter amenities, most people agree they are important, but they do not necessarily relate them to ecological systems. Incentive-based policies are unlikely to be useful for this second category of complementarities.

For the first class, higher levels of these services are usually associated with higher-quality recreation trips. Thus, to the extent these services decline, we can expect the economic values people place on the recreation trips to decline proportionately. Incentive-based adaptation policies are not likely to be helpful in addressing these losses. They can be considered, however, for another likely outcome: increased variability in the services and associated changes in the temporal patterns of recreation use. People will be less willing to substitute different times for a ski trip (or a lake trip) if snow conditions (lake levels) are more highly variable.

Under these circumstances, incentive-based policies can play a role in altering access conditions and fees for the services complementary to the ecosystem services impacted by climate. Opportunities exist to alter the timing of use, the method for rationing the amount of use, and the access conditions to facilities to discriminate among classes of users based on their effects on the environment and on other users.[17] Currently, access conditions are usually controlled with fixed fees (or modest differences in the fees) for all types of use and often do not vary by time of use for public resources.

The primary implication of climate change for incentive-based policies associated with these resources is the opportunity to change pricing for the complementary resources to reduce the peaking effects (and potential damage to ecosystems) from increased variability in the services (and quality) of environmental resources provided by recreation sites. As with the case of substitute resources, it is important to recognize that changes in economic values combined with changes in the temporal distribution of services can alter the outcomes of economic assessments of capacity investments.[18]

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[17] A recent example from conflicts between snowmobile and cross-country skiers at Yellowstone National Park helps to illustrate the issues. Mansfield et al. (2008) found that different types of users of Yellowstone National Park during the winter season had dramatically different preferences for policies limiting snowmobile use. Non-snowmobile riders, for example, were estimated to be willing to pay $762 to ban snowmobiles, while riders who owned their machines required nearly $500 in compensation to accept such a policy. Diversity was also present in other policies to restrict use or limit the use of specific technologies.

[18] For examples of how the access conditions affect simple benefit measures, see Seneca 1970 and Mumy and Hanke 1975.

Augmenting Capacity: The Lessons of Toad Tunnels

Many discussions of adaptation favor capacity-augmenting responses. With water resources, for example, Covich (2009) proposes increasing reservoir capacity and rates of recharge for aquifers. Augmenting through desalination is another way to add to capacity rather than relying on periods of high flow. Similarly, in considering adaptation of terrestrial ecosystems, Running and Mills (2009) suggest pico-dams that can impound water in areas of only a few hectares in the upper cirques of the mountains just below the snowline[19]. For coastal and estuarine resources, Kling and Sanchirico (2009) suggest among other possibilities, land easements, buffer zones, and marine reserves.

Experience with these types of adaptation strategies has been limited. As a result, there is little factual basis for guidance. Consider the experience with a 200-foot-long "toad tunnel" built in Davis, California, under a roadway to avoid automobile traffic killing a Western toad population. The long, dark, hot tunnel was an unusual habitat corridor for a species that does not crawl through tunnels in nature and would possibly be harmed by the hot corrugated steel used to construct the tunnel. Twelve years after construction, the population had disappeared from the area.[20] The "solutions" being proposed to meet climate changes thru innovative forms of infrastructure may face a similar fate and fail to meet expectations. We will not know until they are tried.

Nevertheless, some important conceptual issues do serve to distinguish capacity- and incentive-based policies. One arises in considering the relevance of the conventional arguments for the choice between price and quantity instruments for the use of capacity augmentation as an adaptation policy. Selecting an increment to capacity does not assure a *certain* increase in the levels of the ecosystem services impacted by climate change. In the classic argument offering guidance for the choice between price and quantity instruments, we are uncertain about the incremental costs of meeting a goal for the environmental services involved. Selecting a quantity standard versus a price instrument, in that case, affects the efficiency of the policy. In that situation the instruments are assumed to work with certainty. So picking a quantity assures it will be available and selecting a price assures this is what will face consumers or firms. The situation is different in augmenting a resource that serves as a substitute for a natural service. For example, selecting an augmentation to reservoir capacity (as Covich suggests) or a configuration of pico-dams (as Running and Mills suggest) does not assure the timing and amounts of high water flow

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[19] Pico dams refer to small dams of a few hectares to store water for slow release to contribute to stream flow mimicking the effect of the slower snow melt that may well be precluded under new climatic conditions.

[20] See Sacramento Bee 2007 for a summary. Thanks are due to Nick Kuminoff for suggesting this example.

will be sufficient for the added capacity to provide effective supply or the dams to serve their purpose in reducing habitat degradation with more arid climates.[21]

Of course, the degree of uncertainty in these connections will vary with each potential application. When the production process linking the protective activity to the service flow is uncertain, we cannot apply the same reasoning to support a quantity standard over an incentive-based policy. Suggesting we avoid new “toad tunnels” may get laughs, but the intervention realized no services because the toads continued to cross the road. Thus to argue for capacity augmentation as equivalent to standards that lead to quantity increases requires an understanding of the relationship between those capacity additions and the environmental services they are intended to augment.

It is important to resolve this uncertainty as the increased variability in services and potential changes in pricing or access conditions increases the economic value of capacity expansions that will deliver the services. Thus, evaluations of the net benefits of policy should recognize the effects of the pricing and access regimes likely to be the norm when climate change alters the amount and variability in services contributing to the quality of recreational uses of terrestrial and coastal ecosystems.

Information and Voluntary Behavior

The effects of climate change on the amounts, variability, and costs of delivering market and some non-market goods and services can be thought of as manageable so long as the climate change is not extreme. More frequent, severe, or less predictable storms or extreme events pose different types of threats. Information or voluntary action programs can play important roles provided they are based on insights derived from experiences in responding to these types of problems in other contexts. Extreme events challenge the human and physical infrastructure that sustains everyday activities. Standby capacity of supplies may not be sufficient to meet these needs because they can challenge multiple systems simultaneously –communication, transportation, energy, public safety, etc. What is often needed is a mechanism to induce people to prioritize needs in a consistent way. These types of behavior would assure the greatest needs are met first without the added layer of a formal gatekeeper. Information programs may be able to serve this role.

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[21] Eiswerth et al. (2000) report that the value of water to raise water levels in one of Nevada’s rare perennial, terminal lake sinks is comparable to the agricultural value for the water because the annual value of on-site recreation enhancement due to lake level increase generally matches the value of the enhanced agricultural yields. The case can be made stronger in favor of the lake. This conclusion follows because the amount of water required for the lake annually is less. That is after the initial allocation to raise lake levels, the annual commitment of water required to compensate for evaporation is smaller.

Nonetheless, information programs are not simply a matter of posting the facts but also understanding how to communicate with the intended audience. The same is true for voluntary response programs. In the case of recent experience with calls for voluntary conservation of electricity and water, the incentives for free-riding and varying ability to monitor for non-compliance vary with circumstances. Nonetheless, it appears that consumers do respond to voluntary appeals to modify their consumption behavior for short intervals provided (a) the costs of a collective action failure are tangible and significant, and (b) the public as a whole are well aware of them.[22]

As with pricing policy, conservation is not the only criteria for evaluating voluntary programs. The effect of the level of compliance on provider revenue is an especially notable one. It often raises a "catch-22" outcome for voluntary programs. That is, the revenue effects of voluntary programs, reducing available revenues that public agencies providing service may rely on can lead them to increase fixed charges to compensate for the revenue shortfalls caused by conservation. As a result, customers may respond negatively to the ultimate outcome of their good intentions (i.e. the higher fixed charges) through voluntary individual reductions to avoid collective harms.

Conclusions

Most incentive-based environmental policies focus on *constant* price (or quantity) schedules that vary based on the actions of each individual agent, firm, or household intended to experience that incentive. The pre-positioned policies described here call for incentive systems that can adapt based on the actions of *all* agents as well as changes over time or space in any other *reasonably predictable* conditions that may influence people's choices but are outside their control.

The adoption of dynamic incentive systems that reflect the actions of all users and any variability in related background resources will change the values that private and public agents use in evaluating their investments in climate mitigation. Prices that adapt with changes in the temporal costs of service alter the incremental costs of doing nothing and, as a result, can raise the value of some renewable energy sources in some regions. These enhanced monetary incentives will be larger as more policies promoting dynamic prices for goods that are both substitutes and complements to the climate systems' environmental services are considered.

Most discussions of adaptation focus on investing in new types of capacity to avoid reductions in ecosystem services that might accompany a change in the climate system. This logic assumes the capacity additions provide an assured increment in the services and thus parallel economic arguments for quantity instruments. But conventional economic analyses comparing price versus

[22] See Reiss and White 2008 for discussion of an example of voluntary conservation of electricity. In the case of water, Klein et al. (2007) summarize the results from voluntary conservation programs evaluated at the time of their review, indicating a mixed record ranging from a net increase in water usage of 7 percent to a savings of 33 percent.

quantity instruments under uncertainty are not relevant to evaluating capacity-oriented adaptation policies because these enhancements do not assure an increase in environmental services. This conclusion follows because the link between capacity and these services is itself uncertain.

Finally, when we consider the timing of efforts to use incentive-based adaptation policies, it is important to recognize that efficiency-based reasons to implement them now are independent of the prospect of changes in the levels or the variability in climate-related environmental services.

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