THE ROLE OF MARKETS AND GOVERNMENTS IN HELPING SOCIETY ADAPT TO A CHANGING CLIMATE

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Abstract. This paper provides an economic perspective of adaptation to climate change. The paper specifically examines the role of markets and government in efficient adaptation responses. For adaptations to be efficient, the benefits from following adaptations must exceed the costs. For private market goods, market actors will follow this principle in their own interest. For public goods, governments must take on this responsibility. Governments must also be careful to design institutions that encourage efficiency or they could inadvertently increase the damages from climate change. Finally, although in a few cases actors must anticipate climate changes far into the future, generally it is best to learn and then act with respect to adaptation.

1. Introduction

The emissions of greenhouse gases and their continual buildup in the atmosphere are expected to cause global warming in the next few centuries (Houghton et al., 2001). Even with a well-organized mitigation response, the cost of reducing emissions is sufficiently high, that most experts agree that concentrations will continue to rise through the century and that climate will change (Houghton et al., 2001). Countries should prudently anticipate warming and prepare to adapt to climate change. This paper discusses what role markets and governments should play to encourage efficient adaptation to climate change, how important adaptation is likely to be, and when adaptation will occur.

The paper essentially takes an economic perspective on adaptation. Adaptation is evaluated in terms of efficiency, whether the benefits of actions exceed their costs. In the process of making these judgments, the study relies on a great deal of natural science, making the paper by definition interdisciplinary. Interesting topics from other social sciences such as sociology, anthropology, and political science, however, are not covered in this paper.

Our first task is to define adaptation. In the absence of climate change, each sector of the economy and each nonmarket sector will follow a path into the future subject to population growth, economic growth, technological innovation, and changes in government programs. This path is the baseline for each sector. Climate change will cause damages to climate sensitive sectors and may offer some new opportunities in some sectors. We define adaptation as changes that individuals, firms, or governments make to reduce the damages (or increases the benefits) from

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climate change. The reduction in climate damages (or increase in benefits) is the benefit of adapting. The costs of adaptation are any costs that must be borne to make this change happen. This paper defines efficient adaptation as the set of adaptations that maximize the net benefits of adapting. In other words, an adaptation is efficient only if the benefit of undertaking it is more than the cost. Thus, for example, an adaptation that prevented the loss of $100 worth of crops but cost $200 to undertake would not be considered an efficient adaptation. However, an adaptation that increased the value of water by $101 and only cost $100 to undertake would be efficient.

Efficient adaptation and efficient mitigation are linked. Efficient adaptation reduces the net damages of climate change and so affects the incentive to mitigate. If society does a good job of adapting, they will not need to mitigate as much. Similarly, efficient mitigation reduces the extent of climate change and so affects the need to adapt. If society does a good job of mitigation, we will not need to adapt as much. Climate change policy requires that both of these issues be addressed simultaneously.

But what exactly must be done to encourage efficient adaptation? This paper argues that markets will encourage efficient adaptation in sectors whose goods are traded, such as agriculture, timber, and energy. The market will not be effective encouraging adaptation for jointly consumed goods such as infectious diseases or biodiversity. Efficient adaptation in these sectors will require government support. Impacts in areas with both private and public involvement, such as water, coastal defenses, and heat stress, require a mixture of market (private) and governmental responses to be efficient. Finally, governments often play a role in encouraging or discouraging markets. For markets to be effective, governments have to provide efficient incentives or adaptation may either not occur or become very costly.

We define market adaptation to be private choices that individual firms and households make for their own benefit in response to climate change. Market adaptation therefore has three components, changes in supply, changes in demand, and changes in market conditions. An example of a supply response would be changes that farmers make on their farms in raising crops. An example of a demand response would be changes that consumers make in their energy consumption or conservation plans in response to climate. Finally, if either supply or demand shifts, trading will cause markets to adjust prices. Trading and the signaling of changes in resource scarcity through price changes is a critical final way that markets adapt.

The paper will draw examples of adaptation from several sectors. We begin with agriculture because of this sector's central importance in climate change damage estimates (Pearce et al., 1996; McCarthy et al., 2001; Mendelsohn, 2003) and because the market plays a key role here. We then examine water in order to explore the combination of private and public responses required in this sector. Finally, we talk about a sector where the primary agent of change must be the government. We use as an example, the protection of biodiversity. In each section, we are careful to discuss the dynamics of climate change and the timing of adaptation (Mendelsohn and Williams, 2003). Adaptations that are done too soon or too late can be terribly inefficient.

2. Agriculture-Pure Market Adaptations

A brief review of history teaches us that farmers adapt as the world around them changes. Anthropologists reveal that early civilizations, for example near the Euphrates, entered and retreated from areas as changing climate conditions altered land from being fertile to arid and back (Weiss and Bradley, 2001). More modern farms have an array of adaptations that they can make as climate changes in order to reduce their losses so that retreat is no longer the only option.

Following the agricultural economics literature, we assume that farmers maximize their profits. Although one can always find an individual farmer who appears to have little sense of profits, this model successfully describes a great deal of the observed behavior of farmers. Given the available technology and the prices of inputs (P_x) and outputs (P_q), farmers create the output of crops and livestock (Q), from the inputs of fertilizers, pesticides, machinery, and labor (X) required to maximize profits (π). Each farm is unique in that it embodies a specific set of climate (C), economic (E), and soil (S) characteristics depending on its location. The objective function for the farmer is:

$$\text{Max}\,\pi = P_q Q(X, C, E, S) - \sum X P_x \tag{1}$$

The farmer must choose the output (Q) and variable inputs (X) that maximize profits given the economics, soils, and climate conditions of the farm.

For an individual farmer, the welfare effect of a change in climate will be equal approximately to the change in net revenues for his farm from going from climate C_0 to C_1:

$$W(C_1 - C_0) = [\pi(S, C_1, P_{q1}, P_{x1}) - \pi(S, C_0, P_{q0}, P_{x0})] \tag{2}$$

If the farmer makes no adaptations, no changes in inputs or outputs, then the welfare effect will be equal to the change in production weighted by the prices of output. That is, the change in welfare will be:

$$W = P_q * [Q(X, C_1, E, S) - Q(X, C_0, E, S)] \tag{3}$$

Early estimates of the damages of climate change were based largely on this assumption (Rosenzweig and Parry, 1994). Changes in the productivity of individual crops were calculated from field experiments and then extrapolated to farms based on what they currently grow.

However, farmers are not going to continue to grow the same crops if they start to earn very little, as assumed in [3]. With warming, they can switch to more heat tolerant crops and earn more money. Motivated only by self-interest, farmers will switch crops and planting methods in order to avoid the damages predicted by crop experiments. For example, wheat prefers cool environments. A current wheat farmer would experience a large reduction in yield if he continues to grow wheat in a warmer climate. However, if that farmer switches to growing corn, he will avoid those losses and, in this case, even make a larger profit. The increased net revenue provides the farmer with the incentive to make the efficient adaptation.

The model discussed above looks at a single farmer in isolation. Climate change affects all farmers around the world. The changes facing individual farmers may encourage too much of some crops to be grown and too little of others. One other role that markets perform is to adjust supply and demand across the world. For example, suppose that too many farmers in the US shift away from growing wheat and too many farmers in Russia switch to growing wheat. Prices of wheat in the US will rise and prices of wheat in Russia will fall. The difference in prices will suddenly make it profitable to trade wheat from Russia to the US. Trade and especially international trade will help smooth the changes in production across individual regions, reducing the disparity in prices across regions. However, it still may be the case that fewer farmers are growing wheat across the world and more are growing corn. In this case, global prices will change. The price of wheat will rise and the price of corn will fall. Farmers will receive a price signal to shift to wheat if they can and away from corn. This resulting supply response will reduce the price disparity between wheat and corn. Changing prices thus provides another important feedback in market responses.

Changes in prices are another important market adaptation. In general, aggregate global agricultural production is not expected to change a great deal because of climate change and so agricultural prices are not expected to change much. However, if climate scenarios are mild (severe), global agricultural production will likely increase (fall) at least somewhat. Prices will change to reflect the changing scarcity of food. Rising (falling) prices will benefit (hurt) farmers but hurt (benefit) consumers. Changing prices cause effects to occur around the world, not just in the places experiencing climate change. Both suppliers and consumers will share in these indirect price impacts. Consequently, not all impacts occur in the countries directly affected by climate change. Every consumer and supplier in the world will be affected if global food prices change.

Few studies have explicitly measured how farmers will change production decisions in the face of climate change. Some economic crop models of US agriculture consider crop switching but assume that inputs for each crop would remain the same (Adams et al., 1990, 1993, 1999). Another model of California agriculture considers changing crops and water for irrigation (Howitt, 2005). This model shows that switching water from low valued to high valued crops can make California very resilient to changes in water flows. In one dry scenario, for example, a 25% reduction in water flow to agriculture would lead to only a 6% drop in net revenue. A cross sectional analysis of US farming confirms this California result, showing that irrigation reduces the temperature sensitivity of crops (Mendelsohn and Dinar, 2003). This analysis also demonstrates that sprinkler and especially drip systems might be an important future adaptation by farmers if runoff is reduced. In other words, capital can be substituted for water if water becomes scarce.

How quickly can farmers adapt? Most crops are annual. Even with livestock, there is tremendous turnover in a year or two. Farmers can clearly switch crops rapidly and appear to do so as prices vary from year to year. Of course, some machinery is crop specific and so it would be expensive to shift in and out of a crop each year. But farm machinery is short-lived, typically lasting no more than 5 years and certainly no more than 10 years. Farmers could consequently shift crops 10–20 times over a century without having to retire equipment prematurely. Because climate change will unfold slowly over the century, there is every reason to believe that farmers should adapt to climate change as it is revealed (Kaiser et al., 1993a,b). Farmer's ability to change rapidly reduces their vulnerability to climate change.

Most of the changes that farmers must make to climate change involve their own private resources. The incentives provided by maximizing profits are sufficient to encourage efficient adaptation. There is actually little role for governments in agricultural adaptation. Government policy, however, can affect markets. Governments will need to help allocate surface water, which is discussed in detail in the next section. Second, governments could provide crop insurance. Third, governments could simply subsidize farming.

Crop insurance could help farmers endure a more random future environment. By buying insurance at a rate equal to the expected losses from bad crop years, farmers could smooth out uncertain production levels. For example, if future weather was more uncertain, the crop insurance could protect individual farmers from climate variance. Crop insurance thus provides an excellent opportunity for an institutional adaptation to a future with more climatic variance. In principle, crop insurance should be a private insurance activity. As long as swings in weather are not global but are local, private insurers should be able to balance out good and bad years. However, if every crop growing region in the world simultaneously suffered damages, private insurers may not be able to cope with the magnitude of the losses. In this case, the government would have to be the insurer of last resort.

Governments, unfortunately, have historically done an inefficient job of managing crop insurance. Governments tend to undercharge for crop insurance. As a result, governments, at least in developed countries, have taken a perfectly good insurance idea and turned it into a subsidy. The premiums charged for crop insurance are not able to pay the losses that farmers typically incur. Further, because premiums do not reflect risks, the program encourages farmers to plant in places that are too risky (Makki and Somwari, 2001). As a result, farmers seek adversity rather than try to avoid it. Of course, by charging low premiums, farmers in risky places are made better off. However, from a public perspective, undercharging farmers for insurance actually makes the uncertainty more harmful.

Although crop insurance is useful for avoiding year to year changes in weather, it is not a particularly useful tool for the steady increase in temperature or changes in precipitation that will gradually unfold over many decades. If farmers were insured against this more long term climate change, they would no longer have any incentive to adapt. Instead, they would continue to farm as they do now and allow the insurance program to pay for all losses. Insuring farmers (and other actors) against long term changes in climate reduces adaptation and will increase the damages from global warming.

Farm subsidy programs traditionally encouraged farmers to devote too many resources to growing food and especially crops (some subsidies have been decoupled from production at least in principle to reduce this effect). By adding an additional incentive to price, the government signaled private farmers to increase production. From a climate perspective, this did not necessarily lead to a more climate-sensitive farming sector. However, the subsidies artificially increased the size of the sector. Since damages are a function of how large the agricultural sector is, the subsidies can increase climate impacts. Further, crop subsidies (which are largely available only for developed countries) favor the relatively rich farmers from developed countries over the relatively poor farmers of developing countries. Thus the program has unattractive equity effects.

3. Water-Mixed Market and Governmental Adaptations

In most parts of the world, surface water is scarce. That is, at a zero price, the demand for water across all users exceeds the amount that is readily available. As the world continues to develop, demand is expected to increase. The scarcity of water is expected to increase over time. Markets can play a role in allocating water if the rights to water were better established and tradable. In the absence of markets, governments have a role to play in water allocation. Governments must also be responsible for public projects that provide water to many users through major canals and dams. Both private and public forces must interact to facilitate adaptation in the water sector to climate change.

Water rights are poorly defined in most places around the world. Current users avidly defend their use of water but yet they may not hold legal title to the water. Current users may be able to keep the water they use but they may not be able to sell the water even if they wanted to. There are consequently few examples around the world of water markets.

The absence of water markets has tended to result in government administration of water allocation. Although not all systems have been studied, there is increasing evidence that current water allocations are not efficient. Urban and industrial users of water generally pay more for a marginal unit of water than farmers. Low valued farm uses have a substantial share of available water even when water is a limiting factor for high valued farm uses. This discrepancy in marginal values implies that the overall value of water would increase if water is reallocated from low valued farmers to higher valued users. As especially urban and industrial demand for water continues to increase, water systems around the world will be under increasing pressure to find more water for these high valued uses. This is a serious management problem even in the absence of climate change. If climate change reduces the supply of runoff or increases the demand for water, the problem will become more severe.

Earlier solutions to water shortages focused on finding new sources of water. Three sources were tapped: groundwater, runoff from underutilized watersheds, and desalinized saltwater. All three sources are becoming or always were expensive. Groundwater has become expensive because water tables have dropped after overexploitation. Pumping the remaining water to the surface has become relatively costly. Moving water from one basin to another has always been expensive. This effort, however, is only getting more expensive as the cheapest basins have been tapped leaving only relatively expensive alternatives. It is increasingly unlikely that engineering projects to tap new basins will be cost-effective. Finally, some countries have installed desalinization plants to make fresh water out of salt water. Although there is plenty of salt water available on the planet for this purpose, it takes a tremendous amount of energy to remove salt. Desalinization is consequently very expensive.

The most cost effective water source today is better water management. By diverting water from low valued users to high valued users one can encourage more efficient use of existing water supplies. For example, in most parts of the world, some farmers are using water as though it has a very low price. Yet, in these same watersheds, urban users and often other farmers pay a relatively high price for water. By moving water from low valued users to high valued uses, more water can be made available to high valued users at a lower cost than finding new supplies (Lund et al., 2003). Water management needs to reallocate scarce water from low valued uses to high valued uses. This is primarily an economic problem and so requires an economic solution.

Increasing the efficiency of water allocation is a current water management problem (e.g. Lund et al., 2003). Climate change exacerbates this problem. If water becomes scarcer, the current misallocation of water becomes even more costly. Urban water demand functions are price inelastic (Hurd et al., 1999; Howitt and Tauber, 2003; Lund et al., 2003). If supplies to urban areas are reduced, they involve very large welfare losses. In contrast, the demand for water by low valued farming is price elastic. If the price of water rises, these farmers will reduce their demand for water dramatically. In the absence of prices for water, low valued farmers may continue to use water even when water is scarce. If water is allocated inefficiently across users, the damages from reduced supplies will be higher. The efficient allocation of water is therefore an important adaptation to climate change.

In order to understand the effect of climate on the water sector, it is necessary to build an economic model of water demand and supply (Hurd et al., 1999 or Lund, 2005). For each basin, the model must calculate where runoff is coming from and where it is needed. By allocating water to its highest use, the model can determine the most efficient allocation of water under current conditions. Of course, the allocation would change year to year as supplies fluctuate. By examining the steepness of the demand function of each user, the model could determine where water would go when abundant and when scarce.

The model would also be able to evaluate how water should be allocated if climate changes. Climate change would be like weather changes except that the effects are more long lasting. In a bad weather year, users with price elastic demand would lose water for the year. In a hostile climate, those same users would lose water more permanently. In contrast, users with more price-inelastic demand would be able to pay the much higher price associated with more scarce water. The economic model would reallocate water in response to shifts in runoff to these high valued uses. The economic model would also shift water in response to changing demand. If a warmer climate increases the demand for irrigation for a high valued crop, for example, the model would shift water to the high valued crop and away from low valued crops. The reallocation of water to higher valued users is an important adaptation to climate change.

An important institutional question is who is responsible for this reallocation. In the absence of water markets, the reallocation must be done by the government. The government must restrict the water being used by low valued users and instead give it to high valued users. In practice, governments have a difficult time performing these reallocations because they appear to be zero sum games. For everyone who gets a new cubic meter of water, there is someone else who loses one. Governments have a poor efficiency record of water allocation and may perform this adaptation poorly.

An alternative approach to government allocation is to assign water rights to current users. That is, determine how much water existing users actually receive and grant them permits to continue to have this water indefinitely. If the government then made these property rights tradable, markets could form to reallocate water permits to higher valued uses. High valued users would pay low valued users for each cubic meter of water that they wanted. The trades would compensate the losers, the people giving up the water. The trades, however, would also provide a low cost supply for high valued users. Trading, in this case, would encourage water to migrate from low valued uses to high valued uses. By establishing these water rights today, governments could create a market institution that would handle water reallocation efficiently in the future.

Another important adaptation that would have to be constantly reevaluated is whether to return to engineering solutions to water supply. Although these solutions are expensive, future reductions in runoff may warrant future construction. For example, one change that is expected in the temperate zone is that more precipitation in the winter may fall as rain rather than snow. In the tropical zone, there may also be changes in monsoon rains. Future conditions may warrant that new dams be built to hold some of these off-season rains so that the runoff can be used in the dry periods that follow. Because there would be many beneficiaries of such an effort, the government could well be more efficient at building these dams than private sources. The government may once again have an important role to play.

Once again, however, it is important that governments perform this role efficiently (Mendelsohn and Bennett, 1997). It is critical that new dams or canals be justified by a cost-benefit analysis.

There is an important interaction between the benefits of investing in water infrastructure and the efficiency of water allocation. If water is inefficiently allocated, increasing the supply has a relatively low value. The new water will be worth only what people on average would pay for it. If some of these people place a very low value on the water, the average value of the water will be low. Under scarcity, if water is highly valued, many investments in engineering improvements pass a cost benefit test. However, if the new water is inefficiently allocated, it would have a low value and the infrastructure investment would fail the cost benefit test.

Another important market impact in the water sector concerns hydropower. Changes in runoff will affect the ability of dams to generate hydropower. In general, increases (decreases) in runoff will lead to potential increases (reductions) in power production Changing climate suggests that it will be important for future dam projects to consider changes in runoff. If runoff falls enough, some existing dams may no longer be justified in the future. Similarly, if runoff increases, it may be beneficial to build dams in the future in places that are not cost beneficial today.

Because dams inevitably involve government supervision if not sponsorship, deciding whether or not to change water infrastructure to meet future conditions is an important government role. Because dams are long lasting, it is critical that the government anticipate climate change when considering new construction. First, the government should make a conscious policy of updating runoff records before construction and not depend on historical and possibly outdated flows. Second, the government should consider a range of plausible climate scenarios for the fifty year period after construction. The government should determine what the expected runoff is likely to be and what the cost and benefits will be under each scenario. Weighing these alternative plausible outcomes, the government can use these alternative cost and benefit scenarios to make an informed decision about whether the dam is needed or not.

4. Biodiversity: Pure Governmental Adaptations

An important climate effect that has received relatively little attention is biodiversity impacts. Models of ecosystem-climate interactions suggest that ecosystems will be highly sensitive to climate change (Nielson et al., 1992; Mellillo et al., 1993; Prentice et al., 1992; Joyce, 1995; VEMAP, 1995). Productivity within a system will change because of the combined influence of carbon dioxide fertilization, temperature, and precipitation changes. The boundaries of ecosystems are also likely to shift as most systems will tend to move toward the poles. These changes will cause some ecosystems to shrink and others to expand. For example, most ecosystem models predict that tundra will shrink with warming as boreal forests push up from the south. Species dependent on the tundra ecosystem will experience a shrinking habitat and their numbers will decline. If their numbers were low to begin with, the risk of extinction will increase.

Moving ecosystems will also affect species distributions caught near mountain ranges. As temperatures warm, some species will seek higher altitudes. However, at some point, the highest altitude species will have no place to go. An analysis of ecosystems in California reveals that alpine forests will likely shrink in future climate scenarios (Lenihan et al., 2003). Species dependent on these forests will be at risk. Species dependent on coastal environments may also be vulnerable if they have no place to move. Coastal sage scrubland is especially vulnerable in dry climate scenarios. Combined with the pressure to develop coastal land, coastal sage scrub is in danger of extinction (Smith, 2003).

The threat of climate change raises new concerns for conservation. Current conservation efforts are largely concerned with protecting existing habitat from development. However, if there is an additional threat from climate change, it may be important to anticipate where future habitat should be, not just where current habitat exists. Conservation efforts may have to consider dynamic strategies that move habitat over time, protecting it as a transition is made from a current landscape distribution to a new future order. One strategy is to create habitat corridors so that species can move from one location to another. To adjust to climate change, the key is to open up corridors to the cool side of each current habitat. Another strategy is to practice active ecosystem management by planting and tending desired species. However, rather than focusing on timber species as one would in a plantation, conservation management would focus on endangered species and other species that support the habitat. Silviculturists already know a great deal about creating new environments for desired timber species. The same tools and methods could be applied to create new habitat for endangered species. Although this approach is clearly more expensive than letting nature takes its course, it can be used in special circumstances to create new habitat far from existing locations. For example, if one wanted to jump over a metropolitan area or a mountain range, intensive management could be used to at least establish a new habitat. Nature could then take its course once the new ecosystem has taken hold.

Because there is no private gain from protecting endangered species, one cannot expect that private individuals and firms would take much interest in conserving endangered species. The first line of attack would be to encourage conservation to proceed on public lands. Government agencies responsible for these lands would have to be charged with this task.

The government, however, could take advantage of private lands by providing an incentive for private individuals and firms to create and protect habitat on private land. Conservation payments could be established to encourage habitat for endangered species. If the government provided sufficient incentive, there is every reason to believe that the private sector would voluntarily respond. For example, some former livestock grazing lands are now used to support wildlife for hunting. Private landowners would likely be just as interested in supporting endangered species with conservation payments instead of hunting revenues.

5. Conclusion

Because extensive global mitigation is expensive, climate change is likely to occur over the next century. Countries should expect to adapt to climate change. This paper argues that both markets and governments will play an important role in future adaptation. In general, markets will adapt in sectors dominated by traded goods. The agriculture, timber, and energy sectors are largely market based and so markets are likely to do most of the needed adaptation in these sectors. Government must be careful, in these sectors, not to interfere with market incentives and make matters worse. For example, the government must resist supporting subsidized farm insurance because that may well encourage farmers to forego avoiding risks that climate change will impose. A poorly designed farm insurance program could undercut private incentives to adapt properly to new conditions. Governments must also try not to prevent adaptation for example by insuring against long term changes in climate or by prohibiting market and other systems to change.

Markets will not necessarily make efficient adaptations in sectors dominated by public or jointly consumed goods. In general, markets have not been able to efficiently manage common property, protect unmanaged ecosystems, control pollution, or support public health efforts. Nonmarket goods and services must be managed by the government. In order to develop efficient plans for adaptation, however, governmental entities must begin planning dynamic strategies to protect public goods over time. They must imagine strategies of sea coast protection that unfold gradually. They must encourage natural systems to change in response to warming. They must invest in water improvement projects as they are needed over time and avoid building them too early or too late.

Some sectors involve both private and public resources. Water and coastal management require a combination of market and government interventions to be managed today. Adaptation over time to climate change will also require their joint intervention to be effective. For example, the government can facilitate the development of private water rights so that markets can play an important role in water allocation. If water can be moved from low to high valued users over time, this sector can substantially reduce the impacts of climate change. Governments are also likely to be needed to facilitate coastal protection. Effective coastal protection requires joint actions by neighbors, for example to build a sea wall of a common height. Government support can make such joint action easier by forcing cooperation across diverse actors. Once a sea wall is built, market forces can then determine how to use the protected land behind the wall. The trick for governments is to determine efficient adaptation responses. In the case of sea level rise, that means building walls when they are needed. If the walls are built too soon, the costs skyrocket with little benefit. If the walls are built too late, valuable property gets inundated. Similar concerns apply to building dams and canals. If governments do not anticipate climate change, water infrastructure may be built in the wrong places at the wrong time. Governments must be careful when constructing long-lived structures, that they properly take into account how climate change will affect the use of the structure over time.

Finally, it is important to note that forecasts of climate impacts a century into the future are inherently uncertain. Markets and governments should focus on the climate changes that are likely to occur in the next decade or two but they should be cautious adapting now to climate impacts far in the future. In most cases, very little can be done today to effectively anticipate uncertain changes in 50 to 100 years. Most investments have a life span of only 10–30 years. Only for the most long-lived capital is it important to have a longer time horizon. Second, as time progresses, future adaptations can be planned with the knowledge of what has actually come to pass. By being patient and adapting as climates change, society can learn before it acts and avoid making many mistakes. Actions taken too soon on effects that are not expected to unfold for many decades, will often not turn out as expected and will occur long before they are needed.

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