Facilitating and Aiding Human Decisions to Adapt to or Mitigate the Impacts of Climate Change

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Abstract

Utilizing findings from psychology and behavioral economics, this paper proposes strategies that reduce individuals' cognitive and motivational barriers to the adoption of measures that reduce the impacts of climate change. We focus on ways to encourage reduction in carbon-based energy use so as to reduce greenhouse gas emissions, and encourage investment in adaptation measures to reduce property damage from future floods and hurricanes. Knowledge of individual decision-making processes can guide these prescriptive interventions, such as choice architecture in combination with effectively-framed economic incentives.

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1. Introduction

Fifty years of empirical evidence indicate that human judgments and choices, especially in situations of risk and uncertainty, are influenced by factors considered to be irrelevant by normative theories of choice such as expected utility theory (see Weber & Johnson, 2009, for a recent review). People frequently change their decision when the objectively same choice alternatives are described or framed in different ways, or when the default option is changed. These and other deviations from normative behavior occur because individuals' preferences are affected by the specific decision context (Slovic 1995).

Judgment and choice is influenced by internal states and external circumstances because decision makers' attention, processing capacity, and memory are limited (Simon 1982). To deal with these limitations, perception is selective and valuations are often relative to a reference point (Tversky and Kahneman 1991; Weber 2004). Both deliberative processes and other less effortful modes are used.

In this paper, we examine descriptive models of human judgment and choice from behavioral decision research and behavioral economics to better understand perceptions of and responses to climate change risks. Using empirical insights into how individuals actually make choices under risk and uncertainty, we propose strategies that will encourage individuals to invest in promising measures to mitigate greenhouse gas reductions and help adapt to the impacts of climate change.

The following four examples highlight the challenges for adaptation and mitigation measures as they related to climate change:

Installing Solar Technology and Reducing Energy Consumption

The ***Watt family*** in California is considering whether to spend $15,000 to install solar panels in their home that will reduce their average annual energy expenditures by somewhere between $3,000 and $6,000 over their current system. Solar panels will allow them to lock in long-term electricity rates and protect them from large increases should on-grid utility prices soar due to possible climate change repercussions. The family compared the cost of solar panels with their expected savings in energy expenditures over the next several years, and concluded that it was not worth spending the money on the solar panels. They have some concerns about climate change and are uncertain about its potential negative impacts, such as the higher costs of their electricity. They feel that experts disagree about the magnitude and impact of climate change in the next 20 years, and so decide not to invest in the solar panels today.

The ***Winter family*** in Juneau, Alaska experienced a 45-day power failure in 2008, after a large avalanche destroyed a section of the main hydroelectric transmission line. Backup generators using diesel fuels were the only source of electricity, reducing availability and causing electricity prices to increase by 500 percent.–To save money, every member of the family reduced their energy consumption, from not using the clothes dryer to turning down the heat, switching to CFL bulbs, and reducing the number of bulbs in larger light fixtures. It is not clear whether they will continue to do this in the future.

Investing in Flood Adaptation

The ***Lowland family*** recently moved to the shores of the Missouri River and is considering whether to invest $1,200 in flood proofing their house so it is less susceptible to water damage from future flooding. Hydrologists have estimated that the annual chance of a severe flood affecting their home is 1/100. Should such a disaster occur, the reduction in damage from flood proofing the home is expected to be $40,000. The Lowland family does not believe that it is worth incurring the cost of flood proofing their home since they perceive the risk of flooding to be below their threshold level of concern, even though they are aware that global warming may cause increases in water damage in the coming years.

The ***Waterton family*** in Cornwall, UK experienced several incidents of flooding in their home and their local area caused by major rainfalls, with runoffs that exceeded the capacity of drainage infrastructure. They have decided to invest in flood reduction measures and voluntarily purchased flood insurance to protect themselves again future losses because of these recent events.

The Watt and Lowland families were reluctant to incur the costs associated with investing in adaptive measures respectively for the following reasons:

- Their belief that climate change will not impact them in the near future.
- Uncertainty about economic and social impacts of climate change.
- The impact of immediate upfront costs of undertaking these investments on other consumption needs relative to the perceived expected longer-term benefits of these measures.

On the other hand, the Winter and Waterton families were willing to take steps to reduce their energy consumption and protect themselves against flooding respectively for the following reasons:

- Recent experiences made them aware of the negative consequences from not having electric power readily available or the damages to property and contents that can be caused by a flood.
- The respective incidents in Juneau and Cornwall made the potential impacts of climate change salient to them.
- They focused on the potential benefits from investing in these measures now rather than their long-term expected benefits.

In combination, these four examples highlight the following two points:

- Decisions are made by individuals in ways that differ from normative models of choice such as expected utility theory.
- To encourage individuals to invest in cost-effective adaptation measures, one needs to consider their decision processes and the behavioral factors that impact their choices.

Section 2 examines the processes used by individuals in making decisions and how they differ from normative models of choice. Section 3 focuses on how risk perception and behavioral responses to climate change affect adaptation and mitigation decisions. We then discuss how the private and public sectors can incentivize individuals/households to invest in measures that have economic benefits to them while mitigating climate change and its impacts. The concluding section briefly summarizes the paper and suggests directions for future research.

2. Individuals' Decision Making Processes

The presence of risk and uncertainty raises the following questions with respect to individuals' decision processes: When do individuals rely on their intuition and experience-guided judgment and when do they employ systematic algorithms to evaluate and select choice options? Daniel Kahneman in his Nobel address (2003) and book *Thinking, Fast and Slow* (2011) addresses this question by characterizing two modes of thinking, *System 1* and *System 2* that build on a large body of cognitive psychology and behavioral decision research. [The conceptual distinction goes back to William James (1878) and Heidegger (1962)].

- System 1 operates automatically and quickly with little or no effort and no sense of voluntary control. It uses simple associations (including emotional reactions) that have been acquired by personal experience with events and their consequences.
- System 2 initiates and executes effortful and intentional mental activities as needed, including simple or complex computations or formal logic.

Even though the operations of these two processing systems do not map cleanly onto distinct brain regions and the processes subsumed under the two systems often operate cooperatively and in parallel (Weber and Johnson, 2009), Kahneman (2011) argues convincingly that the distinction between System 1 and 2 helps to make clear the tension between automatic and largely effortless processes and effortful and more deliberate processes in the human mind.

Many of the simplified decision rules that characterize human judgment and choice under uncertainty reflect the influence of the less analytic System 1. Such decisions are guided by the expectations, beliefs, and goals of the decision maker. Often, decisions made by less effortful System 1 processes lead to reasonable outcomes and require much less time and effort than if one were to undertake a more detailed analysis of the trade-offs between options. In this sense they reflect constrained optimization, with attentional and processing capacity constraints causing decision makers to be only boundedly rational (Simon 1982). Decisions using such simplified heuristics and System 1 processes are least effective for choices that require one to focus on long term outcomes that are highly uncertain. Decisions that involve climate change mitigation and adaptation fall into this category.

In cases where the outputs from the two processing systems disagree, the affective, association-based System 1 usually prevails, because its output comes faster and is more vivid, capturing the decision maker's attention over the often more reliable and diagnostic but also pallid statistical information (Erev and Barron 2005).

How does one evaluate the choices made by individuals from a societal perspective? Traditional welfare economics defines a good decision as one that is based on individuals maximizing their discounted expected utility [E(U)] without focusing on the psychological aspects of decision making (Bernheim and Rangel 2009; Robinson and Hammitt 2011). To illustrate this point in the context of the above examples, consider the Lowland family's decision on whether or not to invest in flood-proofing measures that will cost them $1,200 but will reduce flood losses by $40,000 (from

$100,000 to $60,000) if a flood with an annual probability of p= 1/100 occurs. If the family's wealth is currently W and they plan to live in the house for the next T years the discounted E(U) of investing and not investing in flood proofing is given by :

$$E(U)\ [\text{Invest}] = \sum_{t=1}^{T} \{.01\ U(W- 1200- 60{,}000)/(1+\beta)^t + .99\ U(W- 1200)\ /(1+\beta)^t\}$$

$$E(U)\ [\text{Not Invest}] = \sum_{t=1}^{T} \{.01\ U(W- 100{,}000)\ /(1+\beta)^t + .99\ U(W)/(1+\beta)^t\}$$

where β =the annual discount rate, which is assumed to be constant over time.

If the Lowland family were risk neutral (that is, if they perceived the costs of benefits of the two actions proportionally to their actual dollar values), and had accurate information on the probabilities, costs, and expected benefits from investing in flood-proofing measures, they would incur the $1,200 if they planned to live in their house for three or more years if β =.10.[1] Even if they intended to move before that time, they would be willing to incur these costs if they could expect that the property value of their home would reflect the reduced losses from flooding due to their investment in these loss reduction measures. If the family was risk averse and/or $\beta < .10$, they would be even more likely to invest in flood proofing measures for any given value of T.

The Watt family would undertake a similar calculation if they were using the expected utility model to determine whether to invest $15,000 in solar energy panels and their average annual energy bill was reduced by somewhere between $3,000 and $6,000 over their current system. If their wealth was W* then their decision would be determined by comparing the following two options and choosing the one which had the highest discounted E(U):

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[1] Since W is irrelevant when a person is risk neutral, the expected discounted benefits from investing in flood proofing when *β=.10* is

$$.01 \sum_{t=1}^{T} (40{,}000)/(1.10)^t$$

which exceeds $1,200 when T>3.

$$E(U)\ [\text{Solar Panels}] = \Sigma\ U(W^* - 15{,}000 - 3{,}000)/(1+\beta)^t$$

$$E(U)\ [\text{No Solar Panels}] = \Sigma U(W^* - 6{,}000)\ /(1+\beta)^t$$

If the Winter family planned to live in their house for only $T<5$ years, then the solar panel investment would not be worthwhile if the family was risk neutral, unless the property value increased significantly to reflect the savings in energy costs from this investment. In this example, uncertainty exists in the value of T and the projected savings in energy costs in the future due to climate change.

If responses to policy instruments are produced not by rational deliberation that carefully incorporates all past, present, and future information, but are instead determined by a selective and often myopic focus that may be necessitated by processing constraints, policy instruments may not have their desired effect. Policy prescriptions based on realistic processing assumptions may differ from those guided by the assumptions of expected utility maximization.

Dietz (2003) provides a broader and psychologically more realistic definition of what constitutes a good decision, both in terms of processes and outcomes. In the context of environmentally relevant choices, he defines a good decision as one that (1) increases human and environmental well-being, and (2) is also concerned about equity and fairness in both its processes and outcomes. Decision makers should be (3) reminded to draw on all relevant facts and values. They should (4) rely on decision processes that draw on human strengths, rather than (5) be compromised by human weaknesses. The process should (6) also provide decision makers with the opportunity to learn. The first two describe criteria for good decision outcomes, while the last four define qualities of a good decision process that will promote good choice outcomes.

In the four examples highlighted in the Introduction, the Watt and Lowland families made intuitive decisions that focused on relatively short time horizons to evaluate their choice options, rather than engaging in optimal System 2 processes that made appropriate tradeoffs across the relevant time horizon of the decision. The Winter and Waterton families made decisions that were consistent with the ones chosen if they had maximized expected utility, but the basis for their actions were very different. These families also focused on short time horizons but in their case they wanted to take steps to avoid another disaster next year.. The following section examines reasons for this behavior.

3. Risk Perception and Behavioral Responses to Climate Change

A key challenge in designing mitigation and adaptation measures to reduce climate change risks and their impacts is to recognize the limitations of decision makers in dealing with risk and uncertainty. As indicated above, actions are often triggered by automatic and less effortful System 1 processes, rather than by utilizing probability theory to consider the likelihood of uncertain events, choosing the option that maximizes expected utility or engaging in other deliberative and effortful System 2 processes (see Weber 2006, for a review).

In addition to adverse outcomes, two psychological dimensions have been shown to influence people's intuitive perceptions of health and safety risks across numerous studies in multiple countries (Slovic 1987). The first factor, *dread*, captures emotional reactions to hazards like nuclear reactor accidents, or nerve gas accidents, i.e., things that trigger people's automatic fear responses, often because of a perceived lack of control over exposure to the risks and because the consequences are perceived to be catastrophic. The second factor, *unknowability*, refers to the degree to which a risk (e.g., DNA technology) is perceived as scary because it is new, with unforeseeable consequences and with exposures not easily detectable. Both of these reactions show that intuitive perceptions of risk are more a feeling than a statistical concept (Finucane et al. 2000; Loewenstein et al. 2001; Peters and Slovic 2000).

Climate Change Perception

While intuitive perceptions of risk are adaptive and relatively accurate in a broad range of situations, they can lead to systematic deviations from expert assessments, especially for risks that involve small probabilities and high degrees of uncertainty but do not trigger natural reactions of dread. Climate change risks unfortunately have these characteristics. They are low and uncertain probabilities of potentially very adverse consequences that nevertheless do not elicit strong fears, because they tend to be abstract and also have often not been experienced personally (Weber 2006).

To illustrate this point for the Lowland family, a 1/100 probability of flooding with consequences that have never been experienced is an abstract statistic to them. In the absence of a visceral adverse response to flooding, the likelihood of their suffering damage is below their threshold level of concern. Similarly for the Watt family, climate change is an abstract threat that might have relevance for distant continents or future generations, but does not present an immediate and personal threat to warrant their attention. As most people consider themselves experts on the weather and do not differentiate between climate and weather, these risks are not viewed as new or uncontrollable (Bostrom et al. 1994; Cullen 2010).

Laypersons think about climate change in ways different from those of climate scientists, including the use of different mental models (Kempton 1991; Bostrom et al. 1994). When climate change first emerged as a policy issue, people often confused it with the loss of stratospheric ozone resulting from releases of chlorofluorocarbon. As the “hole in the ozone layer” issue has receded from public attention, this confusion has become less prevalent (Reynolds et al. 2010). Today, greenhouse gases are often wrongly equated with more familiar forms of pollution, such as sulfur oxide. People thus make the incorrect inference that “the air will clear” soon after emissions are reduced (Sterman and Sweeney 2007) when, in fact, most greenhouse gases continue to warm the planet for decades or centuries after they are emitted (Solomon et al. 2009). This leads to underestimating the need for immediate action.

Behavioral Responses to Risk and Uncertainty

There are several features of behavior that lead households such as the Watt and Lowland family to decide not to invest in adaptation and mitigation measures.

Relative Encoding, Perceived Losses, and Loss Aversion. Relative judgments are a lot easier to make than absolute judgments: Are you better off today than four years ago? *vs* How well are you off? A natural comparison when evaluating possible choice outcomes is the status quo or another recent event, and our perceptual neurons encode such relative differences rather than the absolute value of objects (Weber 2004). Prospect theory (Kahneman and Tversky 1979; Tversky and Kahneman 1992) introduces such reference-dependent encoding into people's evaluations of consequences and adds another observed regularity: an outcome perceived as a loss relative to the status quo or other reference point is given greater weight than the same outcome perceived as a gain, a regularity labeled *loss aversion*. In other words, people are much more afraid of losing something that they have than of not getting something they want. The upfront and certain costs of the solar panels and the flood protection thus loom large for the Watt and Lowland families, much more prominently than the potential benefits of these investments down the road.

Budget Constraints. The simplest explanation as to why individuals fail to invest in adaptation and mitigation measures in the face of transparent risks is affordability. Leaving loss aversion aside, if the Lowland family focuses on the upfront cost of flood-proofing their house and the Watt family reflects on the costs of installing solar panels and each family has limited disposable income after purchasing necessities, they would choose not to make these investments without undertaking any formal analysis. A budget constraint may also extend to higher income individuals if they set up separate mental accounts for different expenditures (Thaler 1999). Under such a heuristic, a homeowner might simply compare the price of the measure to what is typically paid for comparable home improvements. The family may then decide that flood proofing or solar panels exceeded what they had budgeted for in this account. Such constraints often lead to the use of lexicographic (rather than compensatory) choice processes, where option sets are created or eliminated sequentially, based on a series of criteria of decreasing importance (Payne et al. 1992).

Under-weighing the Future. A fundamental feature of human cognition is that we are influenced more by cues that are concrete and immediate than abstract and delayed ones (Marx et al. 2007). Normative models of intertemporal choice prescribe that we *should* give less weight to distant future outcomes by a constant discount rate, as illustrated above by the Lowland and Watt families if they made their decisions by maximizing exponentially discounted E(U), where outcome valuation falls by a constant factor per time unit delay. In contrast, human temporal discounting tends to be *quasi-hyperbolic,* where outcome valuations fall very rapidly for even small delay periods, so that temporally distant events are given much less weight than they would if they were discounted exponentially (Laibson 1997). As a consequence, the upfront costs of mitigation and adaptation measures loom disproportionately large relative to their delayed expected benefits during the life of the property.

An extreme form of discounting is myopic behavior where the decision maker only focuses on the potential benefits of an investment over the next T periods. Suppose there are significant expected benefits from the adaptation or mitigation measures ten or twenty years in the future due to the impacts of global warming on sea level risk and/or higher electricity costs. If people's time horizon is only two years, then decision makers will not consider these potential returns as they should if they were using normative models of choice such as expected utility theory.

Role of Past Experience in Investing in Adaptation and Mitigation Measures

Recently, a distinction has been made between learning about risky and uncertain events from personal experience vs. numeric or graphic summary descriptions of possible outcomes and their likelihoods. Learning about uncertain events -- be they extreme weather events or possible outcomes of different climate risk mitigation or adaptation responses -- from repeated personal experience capitalizes on the automatic, effortless, and fast associative and affective processes of System 1 (Hertwig et al. 2004).

Learning and responding to updated impressions about the likelihood of different consequences in such experiential environments is well predicted by reinforcement learning models that put a lot of weight on recent experiences (Weber et al. 2004). Such models describe and predict well the volatility of the public's concern about climate change in response to recent weather events, described in the last section. Learning from statistical descriptions, on the other hand, requires System 2 processes (e.g., the interpretation of numerical or graphical probability and outcome information) and are modeled at a normative level by probability and EU theory and at a descriptive level by prospect theory (Kahneman and Tversky 1979).

Focusing on current or recent local weather abnormalities that one has personally experienced can easily lead to misestimations of the climate change risk (Li et al. 2011). This can result in overreactions to recent extreme weather events that have been associated with climate change such as Hurricanes Katrina or Sandy and to dismissals of global warming when going through a spell of cold weather. Public perceptions of the risks of climate change are thus far more volatile than expert estimates (Krosnick et al. 2006).

The evidence is mixed when we examine whether individuals learn from past experience with respect to investing in adaptation or mitigation measures that are likely to be cost-effective. Even after the devastating 2004 and 2005 hurricane seasons, a large number of residents in high-risk areas had still not invested in relatively inexpensive loss-reduction measures, nor had they undertaken emergency preparedness measures. A survey of 1,100 adults living along the Atlantic and Gulf Coasts undertaken in May 2006 revealed that 83 percent had taken no steps to fortify their home, 68 percent had no hurricane survival kit, and 60 percent had no family disaster plan (Goodnough 2006).

This behavior contrasts with the Waterton family who experienced severe losses from rainfall and hence was ready to invest in protective measures. Residents in Cornwall, UK became concerned with climate change and more open to undertaking mitigation and adaptation measures, because the local media linked the increase in rainfall intensity and flood risk to global warming (Spence et al. 2011).

The Waterton family's investment in adaptation measures for dealing with the flood risk is similar to the decision by residents in California to buy earthquake insurance voluntarily following the 1989 Loma Prieta quake and the 1994 Northridge quake. (In contrast to homeowners insurance, earthquake coverage is not required as a condition for a mortgage even in actively seismic states such as California.) In the 1970s, less than 10 percent of the homes were insured against earthquake damage. By 1995, over 40 percent of the homes in many areas along the coast were insured against this risk (Palm 1995). There have been no severe earthquakes since 1985 and the percentage of residents that have earthquake insurance in 2012 has dropped to 10 percent. Similar behavior has been observed with respect to the purchase and cancellation of flood insurance policies even when property owners were required to have coverage as a condition for a federally insured mortgage (Michel-Kerjan et al. 2012). It would not be surprising for the Waterton family to drop their flood insurance if they have not experienced flooding over the next few years.

The tendency to cancel insurance after several periods without any adverse events can be seen as evidence that people view insurance as an "investment" that needs to “pay off” in order to be seen as profitable, and not as protection against catastrophic losses for which it is designed. Such volatility is also consistent with reinforcement learning models that describe decisions from experience, with their built-in focus on recent feedback. In the late 1950s, the chief of police in Crescent City evacuated the entire to town after receiving a tsunami warning, but no wave came and he was ridiculed. In 1963, the residents in Crescent City were warned three times about an approaching tsunami following an earthquake in the Pacific, but none of them occurred. A similar warning the following year after the Alaska earthquake (Magnitude 8.4 on the Richter scale) was ignored by most of the people in the area, but the tsunami did hit the town and killed eleven people (Yutzy 1964; Anderson 1969). Recent stories in the media noted that residents of New York City’s Staten Island failed to evacuate during Hurricane Sandy (with eight getting killed as a result), because they evacuated the year before for Hurricane Irene, after receiving warnings of the severity of the storm to their community that did not occur (Semple and Goldstein 2012).

Turning to investment in energy use reduction or energy efficiency measures, there is empirical evidence that people develop energy-conservation habits when forced to take temporary measures in response to a power shortage or other disruption. The Winter family and other residents of Juneau, Alaska subsisted on a fraction of their previous energy budget for an extended period of time due to severed power lines. Response to this electricity “crisis” included electricity conservation that began within two days of the event and reduced electricity use by 25 percent over the period of supply disruption relative to the same period in 2007. Conservation of about 8 percent relative to 2007 persisted after the transmission line was repaired and electricity rates returned to normal. A second avalanche on January 9, 2009 damaged the same section of transmission line and caused a second supply disruption, albeit shorter in duration (nineteen days) and magnitude of price increase (200 percent). This time observed conservation during the disruption was less (12 percent relative to 2007) while persistent conservation after the event increased by two percentage points to 10 percent relative to 2007. Even after prices went back to normal though, their energy consumption over the next year was down 10 percent compared to previous years (Leighty and Meier, 2010).

These empirical data suggest that when it comes to protecting oneself against losses from natural disasters, individuals at risk hesitate to incur the upfront costs of protective measures, such as the Lowland family's decision not to invest in flood proofing measures that may serve them in good stead for years. On the other hand, flood insurance is viewed as an attractive purchase following a disaster, as illustrated by the Waterton family, presumably because individuals may regret not having had coverage and imagine what they would have saved had they had been protected (Braun and Muermann 2004). With respect to investment in solar technology, households such as the Watt family will be reluctant to incur the investments for solar technology because of its high initial costs but are willing to incur the lower costs of curtailing their use of electricity following power shortages, as illustrated by the Winter family.

4. Strategies for Addressing Climate Change

This section discusses the role that choice architecture coupled with economic incentives can play in encouraging individuals to make decisions that they will not regret after having made them. The use of choice architecture can be complemented by well-enforced regulations and standards that are politically feasible and are designed to improve both individual and social welfare. We illustrate how choice architecture can be applied to the two problem contexts we are considering in this paper with respect to climate change: reduction of energy use and flood adaptation.

Choice Architecture

Choice architecture, a term coined by Thaler and Sunstein (2008), indicates that people's choices often depend in part on how possible outcomes of different choice options are framed and presented . *Framing* typically refers to the way in which outcomes are described as gains or losses relative to a reference point, which can either be the status quo or another value. Choice architects can influence decisions by varying the reference point, order in which alternatives and/or their attributes are presented, and the selection of defaults (see Johnson et al. 2012).

Query theory (Weber and Johnson 2011) documents that people generate more supporting arguments for the choice option that is considered first. This has been observed in numerous lab studies and in real-world settings like elections, where candidates listed first on the ballot have a clear advantage (Krosnick et al. 2001). Arguments in favor of the status quo tend to be queried first, resulting in a strong status quo bias, observed in many contexts (Samuelson and Zeckhauser 1988; Johnson et al. 2007). When CFL bulbs were provided as the no-choice lighting default in a house renovation (vs. incandescent bulbs being the default), choice of CFL bulbs increased from 56 percent to 80 percent (Dinner et al. 2011).

Most choice architecture interventions have focused on choices where the outcomes are known with certainty. Adaptation and mitigation decisions with respect to climate change involve decisions under risk and uncertainty that require one to focus on representing the likelihood of specific events occurring.- An event whose likelihood is extremely small and whose outcome does not elicit a strong affective reaction will tend to be ignored (i.e., treated as if it will not happen). Potential disasters attributed to climate change (such as flood damage from sea level rise) will tend to fall into this latter category, when described as statistical phenomena. As pointed out above, when such low-probability events are experienced, individuals focus on the outcomes and at least temporarily overweight the likelihood of its future occurrence (Weber et al. 2004).

These differences in people's response to low-probability events provide entry points for the design of choice architecture interventions designed to rectify inaccurate and dysfunctional decision weights. Software developed by Goldstein et al. (2008) is an example of an intervention that simulates repeated experience with an event to give people an intuitive feel for the consequences of different probability levels in the domain of consumer finance.

Choice architecture interventions designed to provide decision makers with a different and more accurate intuitive perception of the likelihood of an event, can also draw on *support theory* (Tversky and Koehler 1994; Rottenstreich and Tversky 1997). This is particularly important if the event generates less attention and hence a lower likelihood of occurrence than its probability warrants, Support theory formalizes the frequent empirical observation that the judged probabilities of separate constituents of an inclusive event (e.g., different adverse consequences of climate change, including droughts, fires, coastal flooding, storm surges, malaria increases, etc.) usually sum to more than the judged probability of the inclusive event itself (e.g., adverse climate change consequences), an effect that is mediated by the more concrete nature of the "unpacked" list of constituent events and their greater number, which gives greater opportunity for memory-based retrieval processes to generate available evidence.

A final tool for choice architects is the *certainty effect,* i.e., people's tendency to strongly prefer an option that yields a certain outcome over options that offer the same outcome (or even better outcomes) with only a very high probability. Prospect theory incorporates this effect in its probability weighting function, to describe such choices that are inconsistent with the maximization of expected utility. Guaranteeing certain positive outcomes rather than ones that have a high probability of occurrence should be considered in designing choice architecture interventions as it relates to adaptation and mitigation measures.

We will now illustrate how choice architecture can encourage the Watt and Lowland families to undertake measures that benefit them as well as improve social welfare by reducing the global impacts of climate change.

Encouraging Reduction of Energy Use

Dietz et al. (in press) outline six design principles for encouraging households to adopt energy efficient measures or invest in new energy technologies: targeting actions that have the greatest impact; providing financial incentives; communicating the program smartly; providing accurate information from credible sources; making action simple; and providing quality assurance. Two elements of these principles are that they (a) recognize the importance of describing the decision in a way that will get people to pay attention and (b) that they use financial incentives in a way that overcomes people's reluctance to incur the upfront costs associated with the proposed measure. Information provided must be accurate and come from credible sources. These design principles suggest how choice architecture can be applied to the decision facing the Watt family with respect to installing solar panels in their house.

Framing the Problem. To get the process started, a message needs to be conveyed that makes the decision maker receptive to considering energy efficient measures. Recent research has indicated the importance of highlighting indirect and direct benefits (e.g., being green, energy independence, saving money) in people's adoption of energy efficiency measures (Jakob 2006). One also needs to recognize the importance of political identity considerations when choosing the nature of these messages (Gromet et al. 2012; Hardisty et al. 2012). By presenting the direct economic benefits from adopting these measures, one is most likely to strike a receptive chord. In this regard, the decision should be framed so that the family understands that by investing in solar panels they would be saving money next year as well as in the longer term than if they continued with their current operations.

Structuring Economic Incentives in Psychologically Appealing Ways. Given the importance of providing short-term economic incentives for encouraging investments in solar technology, the solar company could agree to pay the upfront cost of the panels so there would be no initial expenditure by the Watt family. The company would then issue a loan tied to the mortgage, so that the cost of the solar panels will be repaid over the next fifteen, twenty or thirty years by the property owner.

The company would also provide accurate information to households on their annual savings relative to what their energy bill would have been without solar panels. These homeowners can then compare these savings with their annual loan payments to the solar company, because the two amounts are being provided in a comparable metric (i.e., annual amount). To provide short-term incentives that capitalize on the certainty effect, the solar company could guarantee that the monthly annual loan costs would always be lower than the savings in energy costs; portions of the loan payments could be deferred to the next month or the loan extended so the household would reliably save money each month by investing in solar panels, turning this choice option into a dominating alternative, with long-standing evidence that consumers frequently search for dominating choice alternatives, because they strongly dislike tradeoffs (Montgomery 1989).

Solar companies in California such as Stellar Solar (http://www.stellarsolar.net/residential-solar-panel-installation-san-diego.html) have a program similar to this one. It also is the basis of the PACE program adopted by 28 states but viewed by Fannie Mae and Freddie Mac as too risky for issuing a mortgage to homes that have adopted it (Kunreuther and Michel-Kerjan 2011).

To encourage greater energy efficiency in homes, feedback could also be provided to households that compares their energy consumption to those of neighbors. The company Opower has been highly successful in this regard by issuing reports that compare energy usage among neighbors with similarly-sized houses and also include targeted tips for households to lower their energy consumption to the "normal" neighborhood rate. (See http://en.wikipedia.org/wiki/Opower for more information on Opower's activities). Alcott (2011) estimates that Opower's Home Energy Report letters to residential utility customers that provide descriptive norms by comparing their electricity use to that of their neighbors reduce energy consumption by 2.0 percent, with a 6.3 percent reduction for the highest use decile and a 0.3 percent reduction for the lowest decile.

These non-price intervention effects are equivalent to that of a short-run electricity price increase of 11 to 20 percent, and their cost effectiveness compares favorably to that of traditional energy conservation programs. If social norms are established that encourage greater use of energy efficient technology at the household level, this effect will cross to a more macro level by encouraging manufacturers to invest into the R&D of such technology and by encouraging public sector actions such as well-enforced standards of energy efficiency as part of building sale requirements as had been practiced in Davis, CA for thirty years (Dietz et al. in press).

If individual consumers are disinclined to invest in front-cost loaded energy efficiency investments that are nonetheless cost effective, this should also create market opportunities for new services. Appliance companies, for example, could potentially switch their business model from the current one where they sell refrigerators to one where they sell refrigeration services, providing energy-efficient fridges that get frequently updated, as well as the power to run these devices for a monthly fee.

Using Defaults. Energy-efficient and green-energy choice options can be presented to households in a variety of ways that increase their likelihood of being selected. One way is to list the energy-efficient appliances first, for example, at the top of a list of products in a given category, or to provide lists or matrices of products presorted by energy efficiency rather than manufacturer or price. Making energy-efficient products or technology the no-choice default, for example in building codes, is another way to increase uptake of such technology (Dinner et al. 2011). This does not take away any choice autonomy from decision makers who can (but frequently do not) override the specified default. The same holds for the choice between different providers of electricity. For example, making green energy (rather than conventional carbon-generated energy) the default option to German utility customers resulted in a very large percentage of households accepting this option and staying with that option even when feedback about its higher costs was experienced (Pichert and Katsikopoulus 2008).

Adaptation Measures for Flood Reduction

Many individuals exhibit biases triggered by System 1 behavior when they consider whether to invest in adaptation measures to reduce losses from future climate-change related extreme weather events such as flooding. More specifically, they do not pay attention to the consequences arising from the hazard because they perceive its chance of occurrence as below their threshold level of concern. In addition, they have short time horizons, so place too little weight on outcomes that occur ten or twenty years from now that could be impacted by climate change. As a result, the immediate disutility of the upfront cost of the adaptation measure is greater than the discounted expected benefits over the life of the property from investing in this measure.

Choice architecture suggests a number of ways to encourage individuals and households to invest in flood adaptation measures using appropriate System 1 and System 2 behavior to guide households in making the relevant benefit-cost tradeoffs by utilizing accurate information.

Framing the Problem. Research reveals that people are willing to pay considerably more to reduce the risk of adverse events if the likelihood of the event is an imaginable ratio rather than a very tiny abstract probability. For example, saying that the risk of an event occurring when one is protected is half of what it is when one is not protected elicits a far stronger reaction than saying the risk is reduced from .000006 without protection to .000003 with protection. Other studies show that people respond to frequencies rather than relative frequencies or probabilities (Epstein 1994). Thus, presenting a .01 risk as 10 in 1,000 or 100 in 10,000 instead of 1 in 100 makes it more likely that people will pay attention to the event. Most people feel small numbers can be easily dismissed, while large numbers get their attention (Slovic et al. 2000).

Adjusting the time frame also can affect risk perceptions. People are more willing to wear seatbelts if they are told they have a .33 chance of a serious car accident over a fifty-year lifetime of driving rather than a .00001 chance each trip (Slovic et al. 1978). Property owners are far more likely to take flood risk seriously if they are told the chance of at least one flood during a 25 year period is 1 in 5 rather than the comparable annual probability of 1 in 100 (Weinstein et al. 1996). Such information provision programs could be supported by insurers and realtors (programs targeted to their clients) and local, state and federal governments.

One can also unpack the hazard by focusing on the benefits of protection against specific events rather than on a generic class of events. Controlled experiments years before the terrorist attacks of 9/11 revealed that consumers are willing to pay more for insurance against a plane crash caused by terrorists than for flight insurance due to any cause (Johnson et al. 1993). This finding suggests that citing the benefits of protecting oneself against another hurricane such as Sandy might be more successful in attracting interest than a message framed merely in terms of reducing future flood damage.

Two Guiding Principles for Insurance

The National Flood Insurance Program (NFIP) provides a starting point for implementing initiatives that can persuade homeowners to protect themselves against losses from flooding. The recent renewal of the National Flood Insurance Program in July 2012 authorized studies by the Federal Emergency Management Agency and the National Academy of Sciences to examine ways of incorporating risk-based premiums coupled with a means-tested insurance voucher, two key elements in encouraging homeowners to invest in adaptation measures.

These two guiding principles should be utilized in redesigning the rate structure for the NFIP:

1. Premiums would reflect risk based on updated flood maps to provide signals to individuals as to the hazards they face and to encourage them to engage in cost-effective mitigation measures to reduce their vulnerability to catastrophes
2. To address equity and affordability issues, homeowners currently residing in flood-prone areas whose premiums increased and required special treatment (e.g., low income residents) would be given a means tested insurance voucher to reflect the difference.

Structuring Economic Incentives in Psychologically Appealing Ways.

To encourage adoption of adaptation measures against flood damage, flood insurance could be coupled with home improvement loans. Similar to the choice architecture for encouraging adoption of solar energy, long-term home improvement loans could spread the cost of the adaptation measure over a period of years, thus overcoming one's reluctance to invest in adaptation measures caused by a focus on short-term horizons and hyperbolic discounting (Kunreuther et al. in press). Homeowners who invested in adaptation measures would be given a premium discount to reflect the reduction in expected losses from floods whether or not they had an insurance voucher.

To illustrate how the Lowlands would benefit from the proposed program, consider the example presented in Section 2 illustrating the attractiveness of investing in flood adaptation if the family utilized expected utility theory in making their decisions. Under the proposed program, if flood insurance premiums reflected risk, the reduction in the annual insurance premium would be $400 [that is, .01($40,000)]. The adaptation measure costs $1,200, but with a five-year home improvement loan at an annual interest rate of 10 percent, the yearly loan payment will be only $295. The Lowlands would thus save $105 each year by adopting this measure, making it a dominating alternative.

One should also consider tying the flood insurance policy and the home improvement loan to the property rather than to the homeowner. This measure would avoid cancellations of policies when individuals have not experienced damage for several years. In the context of choice architecture, one is more likely to keep insurance when having a policy is the default option (for which no action is required and the premium is folded into the property tax) than if the homeowner is sent a renewal form requesting an active decision that involves payment of the insurance premium for the coming year. Another way to avoid cancellation of policies when individuals have not collected on their insurance is to offer multi-year insurance with annual premiums fixed for a pre-specified time period such as five years.

One motivation for moving to multi-year flood insurance tied to property comes from an in-depth analysis of the entire portfolio of the NFIP that revealed that the median tenure of flood insurance was between two and four years, while the average length of time in a residence was seven years (Michel-Kerjan et al. 2012). Homeowners even allow their flood insurance to lapse, when they are required to purchase flood insurance as a condition for a federally insured mortgage. Some banks and financial institutions have not enforced this regulation for at least two reasons: few of them have been fined and/or the mortgages are transferred to financial institutions in non-flood prone regions of the country that have not focused on either the flood hazard risk or the requirement that homeowners may have to purchase this coverage. Recent estimates show that only half of those living in flood prone areas have flood insurance (Kriesel and Landry 2004; Dixon et al. 2006).

Enforcement of building codes is also necessary to encourage adaptation measures. Following Hurricane Andrew in 1992, Florida reevaluated its building code and also began enforcing a statewide building standard and requiring all licensed engineers, architects and contractors to take a course on the new building code. These actions resulted in greater compliance, initially out of fear of sanctions, but after a while reinforced by descriptive social norms ("everyone else is doing it") and habit. Data from Hurricane Charley revealed that homes built under the new code had a claim frequency that was 60 percent less than those built under the old code (Kunreuther and Michel-Kerjan 2011).

Community leaders may also take steps to convince residents of the importance of investing in adaptation measures so their community is viewed as flood-safe. The leaders can point out that if everyone invests in adaptation, the property values of homes with adaption measures will increase. This message may convince laggards to follow suit by creating a social norm.

5. Conclusions and Future Research

This paper highlights the importance of understanding individuals' perception of risk and their decision processes in developing strategies to invest in adaptation and mitigation measures that promise to improve their individual welfare as well as reduce the consequences of climate change. Based on a rich set of empirical data from controlled experiments and fields studies we conclude that this can be accomplished through choice architecture. By reframing the problem and providing short-term economic incentives, individuals are more likely to focus on the long-term benefits of these measures. When probability information is provided by simulations instead of as abstract numeric probability information, individuals are more likely to focus on the likelihood of an event occurring. Providing information on the behavior of others may help to create social norms.

The expected utility model is the normative benchmark currently used by economists to evaluate individual welfare. In this paper it is the basis for evaluating optimal System 2 decisions to invest in ways to reduce energy use or make one's house more resistant to damage from flooding. What we have learned from research in psychology and behavioral economics is that people frequently behave in ways that are inconsistent with the rational assumptions of expected utility theory. Alternative models that examine preference construction and choice under uncertainty provide better predictions of how people will view climate change mitigation and adaptation decisions, and more importantly, also provide us with entry points for the design of decision and institutional environments that help individuals and societies achieve better decisions.

Future research is needed to examine factors that have been shown to change behavior in deterministic environments to see how important they are in influencing a person's preferences under risk and uncertainty. One will then be in a better position to specify the appropriate use of choice architecture coupled with economic incentives and well-enforced regulations or standards that will affect preferences among options. It will also enable one to develop refined a theory of behavioral welfare economics that can more effectively address ways to encourage mitigation and adaptation measures as it relates to climate change and other social problems.

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