Self Insurance and Insurance Demand under Self-Deception

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Abstract

A dynamic model of self insurance and market insurance demand against uncertain natural hazards is developed where agents incur emotional costs when the true information about potential future catastrophes becomes known. Agents purposefully ignore the incoming signals about future hazards in order to avoid finding out the true information. Faced with the emotional costs associated with true information revelation, self-deception through true information avoidance effort may be the optimal strategy to maximize current and future utility. Government interventions for complementing private risk mitigation and adaptation through incentives and regulations may have a varying influence on such agents exhibiting emotional costs.

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1. INTRODUCTION

When faced with the risk of catastrophic outcomes, individuals often make self protection and self insurance decisions that have been proscribed under the traditional utility maximization paradigms. Examples abound over such anomalies. For instance, people relocate to hazard prone coastal areas despite there being present a significant threat of future flooding. People avoid or tend to discount information if there are psychological costs associated with the information turning out to be true. In order to explain these anomalies, answers have been sought far beyond the rationality assumptions normally imposed on such decision makers. Several psychological factors could be behind some of these seemingly irrational behaviors. First, people exhibit hyperbolic discounting. Second, behavioral aspects could be dominant in their decision making process leading to under-weighting of risks. While the literature concerning these aspects is still evolving, a different explanation is offered in this paper—that of self deception in decision making—which explains why people may continually adjust their risk perceptions so that it allows them to experience the same level of utility even though in reality enhanced risks may have made their actual consumption patterns or decisions highly unsustainable.

Despite the existence of an extensive body of literature on self insurance and self protection (see for instance, Brookshire, et al. 1985, Smith et al. 2006 and Krupnick et al. 2002), current models do not adequately incorporate the psychological aspects of decision making that induce households to make irrational decisions such as relocating within hazard prone coastal communities or nuclear waste sites. While the lure of the enhanced amenity benefits is a prominent factor in some cases, individuals’ refusal to relocate out of hazardous areas is also influenced by their desire to maintain the status quo, as finding out about the true information may hurt more than the actual damages resulting from the realization of the hazard. Psychological Disutility Models (Caplin and Leahy 2001, Barrigozzi and Levaggi 2010), in particular, suggest that people suffer a disutility from discovering a bad information and therefore they may avoid making any effort to find out the true information. The argument is that the psychological disutility from finding out the bad news outweighs the actual benefits from any corrective measures possible after true information is revealed. If such emotional costs are prominent in individuals’ decision making, public

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1 Recent trend towards coastal living, often known as amenity migration, has been documented in Gurran (2008).
2 Recent studies have increasingly highlighted the role of subjective risk perceptions and subjective well being in influencing people’s risk taking behavior. Brereton et al. (2007) show that climate and environmental amenities (especially the spatial ones) play a key role in affecting an individual’s happiness.
incentives and regulations aimed at inducing people to take self protection and insurance measures may fall short of the optimal. The key issue is then over the nature of adjustment in public intervention policies that may be required to help private agents make more judicious decisions when faced with future catastrophic possibilities.

Understanding the role of public intervention to complement private self protection and insurance efforts is crucial towards effectively addressing the challenges faced in mitigating and adapting to environmental hazards. There has been an evolving body of literature following the seminal work of Ehrlich and Becker (1972). Various behavioral aspects of risk have been considered as well. Self insurance and self protection models so far have explained the tradeoffs between protection and insurance efforts in dynamic situations, under multiple risks and under varying risk perceptions (for example, Shogren and Crocker 1991 and Ranjan and Shogren 2009). By extending the notion of psychological disutility to the case of self protection and insurance behavior it is possible to argue that people may refuse to take protective measures because they ignore the incoming signals of future threats from hazards such as coastal flooding due to the associated psychological costs. There is some evidence in the literature over the presence of psychological influences in affecting climate change mitigation behavior. For instance, in case of global warming, individuals who see the cut-back on carbon emissions as a threat to their individualistic life styles are more likely to discount the available information related to global warming (Kahan et al. 2005). See also Berk and Fovell (1999), Weber (2006), Viscusi and Zeckhauser (2006) and Oppenheimer and Todorov (2006) for more illustrations on this idea.

However, the role of psychological costs in influencing such measures has not been adequately considered thus far. Yet emotional costs of information related to bad outcomes could be significant and may deter agents from putting optimal efforts towards discovering the true information. This kind of behavior has been analyzed in the case of agents delaying medical checks to find out whether they are infected with the AIDS virus (Caplin and Eliaz 2003, Koszegi 2003 and Barrigozzi and Levaggi 2010). Agents may even make efforts to mitigate the signals that may reveal the true information in future. When such psychological influences may be strong, self protection and insurance efforts may turn out to be inadequate.

This paper builds on the existing literature to incorporate this key aspect of psychological expected utility models into a dynamic self insurance and market insurance framework in order to highlight the significance of psychological influences in distorting optimal choices under threats from natural hazards. Further, it explores the implications that different means of public intervention may have on insurance, relocation and true information avoidance behavior of
households. Finally, subtle differences between the effects of personal risk perceptions and publicly available risk information on information avoidance efforts are also analyzed.

2. MODEL OUTLINE

The analysis presented here is motivated using the case of coastal hazards, however, it is generalizable to other cases including location decisions near nuclear waste sites or health risk related decisions. Consider a household located in close vicinity of a flood prone coastal area. Currently, it does not take any protective or insurance measures to guard itself against a future coastal hazard. There are mainly two options available. It can either choose to relocate away from the coastal region to minimize damages in case of flooding or buy adequate insurance cover or could pick some measure of both. Risk of flooding in future is publicly known but may not be accurate. In addition to the flooding risk, there is also information arriving in every time period that could remove the uncertainty over the inaccuracy of the publicly available risk estimates. There is a chance that future information would remove this inaccuracy, which could be either a complete negation or a full ascertainment of the risk. The household selectively picks information arriving in each period that either discounts or validates this risk.\footnote{Households could be made aware of the actual flooding risk through information disclosure requirements for mortgage lenders and through media coverage. However, perceived risks may still remain resistant to changes as the literature suggests. Gayer et al. (2000 and 2002) show that the perceived risks of cancer at superfund sites fall after release of remedial investigation by the Environmental Protection Agency. Similarly, Bezdek and Wendling (2006) argue that the presence of nuclear facilities near housing sectors does not necessarily depress the property values. However, in certain cases the findings indicate that the presence of spent nuclear fuel or other hazards may actually depress property prices in the neighborhood (Clark and Allison 1999 and McCluskey and Rausser 2001).} If it chooses to pick information at its full face value, the chance that it will acquire the true information about the real situation in the future increases. Whereas, it can also discount the incoming signals and remain ignorant for as long as it prefers. An effort is required to discount these signals which could be costly. Once the true information is revealed, the household comes to know whether the flooding risks are real or not. If the flooding risks are real, it is forced to take optimal insurance measures. If the risks turn out to be false, then it does nothing for the rest of its time horizon. Also, there is a chance that flooding happens before the true information is revealed, in which case the household suffers damages based upon its location, property value and forgone amenity values.

Based upon the above storyline, the outline of the rest of the paper is as follows. First, a model of optimal self insurance and market insurance efforts is
designed when the household knows the flooding risk to be accurate and takes adequate measures. Then, in the next section, a dynamic psychological disutility model is designed and the previous model is appended to it. The new model lets the household postpone the acquisition of information on the risk of flooding as an optimal control variable subject to the constraints posed by the dynamics of risk of flooding and the risk of true information being revealed. Given these new constraints, the household re-optimizes.

2.1 A SELF INSURANCE AND MARKET INSURANCE DEMAND MODEL

Assume that a representative household is faced with a decision over locating in a coastal region. However, the current trend in sea level rise projects a high probability of catastrophic floods in these coastal regions in future. Suppose that the household faces a flooding hazard $q(t)$ at any given time $t$. The probability of flooding is characterized by a random event with an exponential distribution, the hazard rate of which is given by $\lambda(t)$ and is defined as:

$$\dot{\lambda}(t) = q(t)$$

The hazard rate of flooding may comprise endogenous and exogenous elements. The exogenous element is beyond the control of the household. However, it can reduce the endogenous component by self protecting. Self protection and self insurance in this context may involve moving to high elevation areas and moving farther away from the coastal region. However, in the present dynamic context of the model, the cumulative risks of flooding are assumed to be exogenous and independent of the past protection measures of the household. For simplicity, it is assumed here that the household can move away from coastal region to minimize the damages, but the risks of flooding are equal for all residents in the concerned region. This could be possible when the entire residential settlement is located on a level elevation. In reality, residents located farther away from the ocean area or in houses with higher elevations (such as houses on stilts) could face a lower risk. Self protection in this case would lower the risk of flooding. However, we assume households can self insure but cannot self protect in order to keep the analysis tractable and focused on subjective aspects of these risks such as self deception.\footnote{A case of self protection can easily be included in this model by making flooding risks a function of a house elevation variable. Optimal location and risk mitigation decisions in this situation would consider the tradeoffs between locating farther way to reduce the damages versus locating higher above to reduce the risks.}
The proximity to the coastal region is represented by a parameter \( s(t) \) in the above equation. When \( s(t) \) is zero, the proximity is maximum. This also yields maximum amenity value \( z(t) \) at time \( t \). If the household moves away from the coastal area, the amenity value is reduced by a factor \( (1-s(t)) \). Let the accumulated sum of the hazard rate be defined by the variable \( \lambda(t) \), where\(^5\):

\[
(2) \quad \lambda(t) = \int_0^t q(x) \cdot dx,
\]

The location variable \( s(t) \) insures the household by reducing the extent of damages. The household self insures itself in case of a flooding catastrophe following which the level of flooding damage is given as:

\[
(3) \quad d(t) = (1-s(t)) \cdot k(t),
\]

In the above equation, the damages from flooding are maximum when \( s(t) \) is zero. If the household moves to the farthest point of the region, \( s(t) \) is 1 and the damages are zero. \( k(t) \) is the value of the household’s property and is assumed to grow over time at the market rate of interest.\(^6\) Presence of risk related information may impact on housing values. However, the literature points to a marginal impact of such information on housing values.\(^7\) Additionally, the household can buy market insurance, \( i(t) \), to receive compensation for any flooding damage.\(^8\) Assume that an actuarially fair insurance market exists that charges an insurance premium equal to the risk of the catastrophe occurring before time \( t \), where the latter is given as:

\[
(4) \quad 1 - \exp(-\lambda(t)) = 1 - \exp\left(-\int_0^t q(x) \cdot dx\right)
\]


\(^6\) In a more realistic scenario, the property value would also be affected by the increased risk of flooding in future and its future value could be weighted by the survival probability to look like \( k(x) \cdot j \cdot k_i \cdot \exp(-\lambda(t)) \), where \( k_i \) is the factor by which the future property value may decline if the probability of flooding happening after time \( t \) were \( \exp(-\lambda(t)) \).

\(^7\) Troy and Romm (2004) point out that disclosure of wildfire risks to properties located within the fire perimeters reduced housing prices by about 5 percent.

\(^8\) Recent findings also suggest that flood insurance premiums charged by insurance providers adequately reflect the risks of flooding (Bin et al. 2008).
In the above equation, the probability of surviving without any flood occurrence up to time $t$ falls to zero as time becomes large. Therefore, the probability of flooding happening before time $t$ reaches 1. This would imply that the household must eventually pay the entire value of the property as insurance premium when the probability of flooding hazard has reached one.

The utility to the household in the pre-catastrophe scenario $U_{pre}$ comprises utility from wages and the utility from property net of any market insurance and self insurance expenses and is given as:

$$U_{pre} = \int_{0}^{t} \log\{w - i(x) \cdot (1 - \exp(\lambda(x))) + z(x) \cdot (1 - s(x)) + k(x) \cdot j}\, dx$$

The household derives utility in three different ways. First from consuming its wages, second through the amenity values derived from being close to the coastal area and third from the utility derived from the property. The amenity value is given by the term $z(x) \cdot (1 - s(x))$. The utility from the property is given by the term $k(x) \cdot j$ where $j$ translates the value of the house into utility. That is, the higher the value of the house, the more features it may contain leading to a larger utility. All three components of the utility are weighted by a logarithmic factor. The utility in the post flooding scenario $U_{post}$ is given as:

$$U_{post} = \int_{t}^{\infty} \log\{w + k(x) \cdot j \cdot s(x)\} \cdot \exp(-r \cdot x)\, dx + \log(\min(i(x), (1 - s(x)) \cdot k(x)))$$

$$= \log\{w + k(x) \cdot j \cdot s(x)\} + \frac{\log(\min(i(x), (1 - s(x)) \cdot k(x)))}{r}$$

In the post flooding scenario, the household continues to get fixed wages in addition to a onetime payment equaling minimum of insurance purchased and the damages to the property. Note that the higher the value of $s(x)$, the lower will be the damages. In addition, the household also has the undamaged portion of the house as given by the term $k(x) \cdot j \cdot s(x)$. Since, after flooding, $s$ is assumed to remain the same forever, the utility provided by a constant stream of wages and future utility from the remaining house can be summed to infinity get the term
The household’s expected utility function summing the pre and post catastrophe scenarios $E[U_0]$ is given as:

$$E[U_0] = \int_0^\infty \exp(-\lambda(t)) \cdot \exp(-r \cdot t) \cdot \log\left( w - i(t) \cdot (1 - \exp(\lambda(t))) + z(t) \cdot (1 - s(t)) + k(t) \cdot j \right) \cdot dt + \int_0^\infty q(t) \cdot \exp(-\lambda(t)) \cdot \left( \frac{\log\left( \frac{w + k(t) \cdot j \cdot s(t)}{r} \right)}{r} + \log(\min(i(t), (1 - s(t)) \cdot k(t)))) \right) dt$$

The current value Hamiltonian is given as$^{10}$:

$$\exp(-\lambda(t)) \cdot \log\left( w - i(t) \cdot (1 - \exp(\lambda(t))) + z(t) \cdot (1 - s(t)) + k(t) \cdot j \right) + \exp(-\lambda(t)) \cdot q(t) \cdot \left( \frac{\log\left( \frac{w + k(t) \cdot j \cdot s(t)}{r} \right)}{r} + \log(\min(i(t), (1 - s(t)) \cdot k(t)))) \right) + m(t) \cdot q(t)$$

where $m(t)$ is the shadow price of the accumulated risk. First order condition with respect to location decision yields:

$$\exp(-\lambda(t)) \cdot \frac{z(t)}{\left[ w - i(t) \cdot (1 - \exp(\lambda(t))) + z(t) \cdot (1 - s(t)) + k(t) \cdot j \right]} = \exp(-\lambda(t)) \cdot q(t) \cdot \left( \frac{k(t) \cdot j}{r \cdot (w + k(t) \cdot j \cdot s(t))} + \frac{(0, if \rightarrow i \leq (1 - s) \cdot k, \& - k, if \rightarrow i > (1 - s) \cdot k)}{\min(i(t), (1 - s(t)) \cdot k(t))} \right)$$

Notice that the optimal relocation decision is not independent of the insurance choice. The first order condition requires that the negative impact of location on amenity value be weighed against the reduced expected damage to the property from flooding under an optimal insurance demand. An indirect impact of this requirement is that if amenity values increase in future, then flood risks have to increase significantly as well in order to discourage coastal residents from living in flood prone regions. This may not be an unlikely scenario. Given the three components of the utility function, the amenity value is the only one that may increase in future if one were to deviate from standard utility assumptions and draw from emerging alternative theories such as those proposed under happiness.

$^9$ Assume that, upon flooding, the house value stops growing in future.

Happiness economics argues that once a threshold of income is crossed households may see very limited increase in their happiness with a further increase in their income. In such cases, the amenity value component may start to bear heavily on the overall utility of the households.

The first order condition for insurance demand requires that the increased cost of insurance be adjusted by the increased benefits from it under an optimal location decision as:

\[
\begin{align*}
\exp(-\lambda(t)) & \cdot \frac{(1 - \exp(\lambda(t)))}{\{w - i(t) \cdot (1 - \exp(\lambda(t))) + z(t) \cdot (1 - s(t)) + k(t) \cdot j\}} \\
& = \exp(-\lambda(t)) \cdot q(t) \cdot \frac{\left\{1, \text{if } i \leq (1 - s) \cdot k, \& 0, \text{if } i > (1 - s) \cdot k\right\}}{\min(i(t), (1 - s(t)) \cdot k(t))}
\end{align*}
\]

In addition, the shadow price of accumulated risk grows as:

\[
\begin{align*}
\bar{m}(t) &= \exp(-\lambda(t)) \cdot \log\left\{w - i(t) \cdot (1 - \exp(\lambda(t))) + z(t) \cdot (1 - s(t)) + k(t) \cdot j\right\} - \\
& \quad \exp(-\lambda(t)) \cdot i(t) \} \\
& + \exp(-\lambda(t)) \cdot q(t) \cdot \left\{\frac{\log\left\{w + k(t) \cdot j \cdot s(t)\right\}}{r} + \log(\min(i(t), (1 - s(t)) \cdot k(t))) + r \cdot m(t)\right\}
\end{align*}
\]

The shadow price of the accumulated risks evolves over time at the rate of discount (which may capture market rate of interest as well as the household’s inter-temporal time preferences) in addition to the expected per period utility from pre and post flooding events. Note that an enhanced amenity value in future would increase the growth in shadow price of risks (as the second term on the right hand side is negative in sign). This is also because of the assumption that the household may not be able to enjoy any amenities in the post flooding scenario. However, if the property value were to decline with risk then the growth in the shadow price of risk could decline as well. This should be intuitive, as flooding adversely impacts property and if property value is lowered disproportionately as risk increases, the expected damages from an increase in risk could decline.
2.2. SELF INSURANCE AND INSURANCE DEMAND UNDER SELF DECEPTION

Now, consider that the household ignores the information being received about the accuracy of flooding risks, as it suffers a disutility from acquiring this information. That is, if it finds out that the risk of flooding is accurate, it will suffer a psychological disutility \( \xi \) from this revelation which may outweigh the damages incurred from the actual flooding. In order to formalize this idea, consider that there is a certain chance of the household becoming fully aware of the true risks of flooding at a given period of time. This chance follows a Poisson process and its hazard rate is given as \( \dot{\phi}(t) \). This hazard rate can be influenced by a conscious effort on the part of the household by cherry-picking information that perpetuates its current beliefs about the threats of flooding. Specifically, the hazard rate is defined as:

\[
\dot{\phi}(t) = f_1 e^{-f(x)}
\]  

where \( f(t) \) is the effort put towards avoiding the actual signal related to flooding risks in each year and \( f_1 \) is some constant level of hazard that manifests when no effort is undertaken. The household may incur a cost \( c(f(t)) \) in each time period for trying to cherry-pick the desired information from the incoming signals. The accumulated hazard rate governing the possibility that the household will eventually come to know the true information at time \( t \) is given as:

\[
\phi(t) = \int_0^t \dot{\phi}(x)dx = \int_0^t e^{-f(x)}dx
\]

When this information is revealed, the household is forced to take the optimum decision derived in section 2.1 which yields an expected utility \( E[U_0] \). However, this expected utility will vary with the stock of accumulated hazard \( \lambda(t) \) at the time the household realizes this true information. This is because a higher starting level of cumulative hazard would require a higher self insurance and market insurance efforts. Therefore, the value function to the household in the event of realizing this true information is a function of \( E[U_0] \) and \( \lambda(t) \). Let’s call this value function \( V_1(E[U_0], \lambda(t)) \). Now, one possibility is that when the household gets the true information it may find out that the possibility of flooding is real. However, there is also a possibility that the true information may actually reveal that there is no flooding risk in future. Let the prior held by the household over
the risk of actual future flooding be given as \( p \). So, the household’s expected utility \( A(t) \) in the event of revelation of the true information can be written as\(^{11}\):

\[
A(t) = p \cdot V_1(E[U_0], \hat{\lambda}(t)) + (1 - p) \cdot V_0(t)
\]

Where \( V_0(t) \) is the value derived when the household will not need to take any insurance and mitigation efforts after finding out that the flooding risks were unreal and is given as:

\[
V_0(t) = \int_0^{\infty} \log\{ w + z(x) + k(x) \cdot j \} \cdot \exp(-r \cdot t) \cdot dx
\]

Now, the household’s overall problem can be broken into three parts as follows: (a). value before either the true information about flooding possibility or actual flooding is realized\(^{12}\):

\[
\int_0^{\infty} \{ \log(w + z(t) + k(t) \cdot j) - c(f(t)) \} \cdot \exp(-\hat{\lambda}(t) - \phi(t)) \cdot \exp(-r \cdot t) dt
\]

(b). value after the true information about flooding possibility is realized:

\[
\int_0^{\infty} (-\xi + A(t)) \cdot \hat{\phi} \cdot \exp(-\phi(t)) \cdot \exp(-r \cdot t) dt,
\]

and (c). the value after flooding happens\(^{13}\):

\[
\int_0^{\infty} V_2(t) \cdot \exp(-\hat{\lambda}(t)) \cdot \exp(-r \cdot t) dt
\]

\(^{11}\) Three different risk types have been introduced thus far. The first one is \( \hat{\lambda}(t) \) or \( q(t) \) which is the hazard rate of flooding that is being made known to the household by the public agencies. Second, \( p \) is the prior that the household holds on the actual risk of flooding. The third risk type is \( \hat{\phi}(t) \), which is the hazard rate of true information (which could be either flooding or no-flooding) being known in future.

\(^{12}\) The cost function \( c(f(t)) \) is assumed to be additively separable from other arguments of the household utility function and is not weighted by the logarithmic term.

\(^{13}\) This assumes that the household is located closest to the ocean initially.
The overall optimization problem can be put together as:

\[ U_1 = \int_0^\infty \left( \log(w + z(t) + k(t) \cdot j) - c(f(t)) \cdot \exp(-\lambda(t) - \phi(t)) \cdot \exp(-r \cdot t) \right) dt + \int_0^\infty (-\xi + A(t)) \cdot \dot{\lambda} \cdot \exp(-\phi(t)) \cdot \exp(-r \cdot t) dt + \int_0^\infty V_2(t) \cdot \dot{\lambda} \cdot \exp(-\lambda(t)) \cdot \exp(-r \cdot t) dt \]

where \( V_2(t) \) is defined as:

\[ V_2(t) = \int_0^\infty \log(w - z(t) \cdot (1 - s(t)) - k(t) \cdot j) \cdot \exp(-r \cdot t) \cdot dt \]  

and is the value derived after a flooding happens at time \( t \) and its property and amenity values are lost forever. We have now adjusted the utility derived after the true information about flooding possibility is revealed in order to account for the psychological loss from knowing this bad information. This loss is given by \( \xi \). In the literature, this psychological loss has often been treated as being endogenous (for instance, see Caplin and Leahy 2001). Later on we will explore the implications for adjustment in this psychological cost in the dynamic optimization context.

If \( \xi \) is larger than \( A(t) \), the household’s psychological loss from knowing the true information is more than the expected gain from avoided damages after knowing the true information. The household maximizes equation (19) with respect to information avoiding effort \( f(t) \).

The household maximizes the above problem with respect to the information avoidance effort subject to the constraints posed by the equations of motion for the rate of accumulation of true information related signals and the publicly known rate of flooding hazard \( \dot{\lambda} \). Note that the optimal self insurance and market insurance efforts are already solved for in the value functions \( E[U_0] \).

The current value Hamiltonian can now be written as:

\[ \begin{align*}
(\log(w + z(t) + k(t) \cdot j) - c(f(t)) \cdot \exp(-\lambda(t) - \phi(t)) + (-\xi + A(t)) \cdot \dot{\phi}(f(t)) \cdot \exp(-\phi(t)) + \\
V_2(t) \cdot \dot{\lambda} \cdot \exp(-\lambda(t)) + m \cdot \dot{\phi}(f(t)) + n \cdot \dot{\lambda}(t)
\end{align*} \]

where \( m \) is the shadow price of the accumulated hazard that yields true information and \( n \) is the shadow price of accumulated risks of flooding. First order condition with respect to \( f(t) \) gives:
\[ -c'(f(t)) \cdot \exp(-\lambda(t) - \phi(t)) + (-\xi + A(t)) \cdot \dot{\phi}(f(t)) \cdot \exp(-\phi(t)) + m(t) \cdot \dot{\phi}'(f(t)) = 0, \]

which can be re-written to derive the value of the shadow price of true information as:

\[
m(t) = \frac{c'(f(t)) \cdot \exp(-\lambda(t) - \phi(t))}{\dot{\phi}'(f(t))} + (-\xi + A(t)) \cdot \exp(-\phi(t)) \tag{23}\]

Optimum true information avoidance effort must be equated to the shadow price of accumulated risk of the true information \( \phi(t) \) being revealed. The shadow price of \( \phi(t) \) is a sum of two parts. The first part is the additional discounted cost from an extra information gleaning effort, where the discount rate is the rate of change of the hazard function for true information arrival. The second part is the difference between the psychological disutility from information and the expected value after true information is revealed. The higher the two terms, the higher would be the cost of increasing the stock of accumulated hazard related to true information. Further, the no-arbitrage condition for the shadow price of accumulated hazard of true information requires:

\[
m(t) = \log(w + z(t) + k(t) \cdot j - c(f(t))) \cdot \exp(-\lambda(t) - \phi(t)) + (-\xi + A(t)) \cdot \dot{\phi}(f(t)) \cdot \exp(-\phi(t)) + r \cdot m(t) \tag{24}\]

Substituting from above for \( m(t) \) we get:

\[
\dot{m}(t) = (\log(w + z(t) + k(t) \cdot j - c(f(t))) \cdot \exp(-\lambda(t) - \phi(t)) + (-\xi + A(t)) \cdot \dot{\phi}(f(t)) \cdot \exp(-\phi(t)) + r \cdot c'(f(t)) \cdot \frac{\exp(-\lambda(t) - \phi(t))}{\dot{\phi}'(f(t))} + r \cdot (-\xi + A(t)) \cdot \exp(-\phi(t))) \tag{25}\]

Next, the obvious question is over the nature of evolution of this psychological disutility. So far, it has been assigned a constant value. But from an empirical perspective, if risks increase but people still do not change their behavior, the psychological disutility must rise to compensate for that enhanced risk. In order to see the relationship between the increase in risk and the required change in psychological disutility we differentiate equation (25) (using the implicit function theorem) with respect to accumulated risk \( \lambda(t) \) and \( \xi \) to get:
\[ \frac{\xi}{\lambda} = \frac{\partial \bar{m}(t)}{\partial \lambda(t)} = A'_p + \frac{(A_0 - c(f(t)) \cdot \exp(-\lambda(t)))}{-\phi + r} + \frac{r \cdot c'(f(t)) \cdot \exp(-\lambda(t))}{-\phi + r} \]

(26)

where the term \( A_0 \) is defined as \( \log(w + z(t) + k(t) \cdot j) \), which is positive. If \( A_0 > c(f(t)) \) and \( \phi < r \) and the expected value function upon revelation of true information given by the term \( A \) decreases in \( \lambda \), then the first and the third terms would be negative whereas the second term would be positive.\(^{14}\) If the second term is positive and dominates the other two terms, then an increase in flooding risk must lead to an upward revision of the emotional costs for the household to be able to maintain the status quo. The second term is basically the per-period benefit to the household from doing nothing net of any information reduction costs. If these benefits are large, say for instance from a large amenity value, then the household would revise its emotional costs upwards whenever the risk of flooding increases. Whereas, if the first and the third terms dominate the second term, the household would revise its emotional costs downwards with an increase in risks. We can also look at the emotional cost adjustments with changes in the priors held by the household (given by probability \( p \)) over the flooding risk.

\[ \frac{\partial \xi}{\partial p} = -\frac{\partial \bar{m}(t)}{\partial \lambda(t)} = A'_p \]

(27)

The term \( A'_p \) will be negative (as \( E[U_0] < V_0 \), as \( V_0 \) is the unconstrained optimum when the household is located the closest to the ocean and faces no flooding risks) and therefore, the emotional cost must be revised downwards to remain in a steady state. Note that the key difference between the priors \( p \) and the publicly projected risk of flooding \( \lambda(t) \) is that the latter is controllable by the household through its information avoidance effort and therefore leaves ambiguity over the direction of the change in emotional adjustments. The priors on the other hand are fixed as these are the fundamental beliefs that the household holds over true states of the world in the future and are slow to change or unchangeable.

\(^{14}\) Note that the expected value may increase with flooding risk because the optimal behaviour may require relocating away from the hazard prone area, thus reducing the expected damages and insurances costs.
2.3. POLICY IMPLICATIONS

From a societal perspective, what can the government do to deter true information avoidance behavior? The key question is over the influence of policy intervention on true information reducing effort. In order to see how this effort is affected by the changes in the expected value, $A(t)$, we differentiate equation (25) with respect to $A(t)$ and $f(t)$:

$$\frac{\partial f(t)}{\partial A(t)} = \frac{\partial \hat{n}(t)}{\partial A(t)} = \frac{\phi(t) - r}{c'(f(t)) \cdot \exp(-\lambda(t)) - (A - \xi) \cdot \phi'(t)}$$

(28)

The sign of the above term is ambiguous. If $\phi(t) - r < 0$ and $A - \xi > 0$, then $\frac{\partial f(t)}{\partial A(t)}$ would be negative. What this means is that when the expected value in the state when true information is revealed is higher than the emotional cost, the effort to reduce true information would decline with an increase in $A$. However, when $\phi(t) - r > 0$ and $A - \xi > 0$ the effort will increase. This is because when the hazard rate for revelation of true information is higher than the rate of discount (or time preference) then it pays to try to reduce information signals. Analogously, when $\phi(t) - r < 0$ and $A - \xi < 0$, then $\frac{\partial f(t)}{\partial A(t)}$ could increase with an increase in $A$.

In this case the emotional costs are higher so it is intuitive to raise effort that reduces true information as long as the costs of this effort aren’t too high thereby making the denominator positive.

Next, we need to consider the factors that may lead to an increase in $A(t)$ from a policy perspective. Specifically, let us explore the effects of insurance subsidies and regulations related to coastal relocation on $A(t)$. In order to explore the role of an insurance subsidy, we need to revisit equation (7) which solves for the expected utility for a self insurance and market insurance problem. The cost of insurance is given by the term $i(t) \cdot (1 - \exp(\lambda(t)))$. If this cost is subsidized, the optimum response may be to buy more insurance and live closer to the ocean (by increasing $s(t)$). This increases expected utility by increasing the amenity value but also reduces it by increasing the risk of flooding damages. The overall impact will, however, be positive under an optimal decision. This is confirmed later through a numerical example. Next, consider the impact of a regulation
requiring relocation away from the coastal zone. Now, this will increase the expected utility function by reducing the risks, but may also decrease it by reducing the amenity value. There are several ways in which the amenity loss could exceed the risk reduction effect. First, if the amenity value is non-linear in $s(t)$ or is very high, it will reduce the overall utility. This could be entirely possible in reality as most coastal settlers belong to the amenity migration category with high values for coastal living. Second, the expected utility may decline if the insurance cost is cheaper than the amenity value loss. The insurance cost may be cheaper if there are existing subsidies, or if the risk is lower. Note that the risk is also a factor in insurance costs. Risks may be lower either because actual risks are lower or if perceived risks are lower in the insurance market as well. For all these reasons, the regulation of relocation may lead to a reduction in $A(t)$. Now, following the above result, if $A(t)$ is reduced, true information reduction effort could go up. Therefore, while insurance subsidy leads to a reduction in true information reduction effort, the same cannot be said of a relocation related regulation.

3. A NUMERICAL ILLUSTRATION

Let us briefly consider a numerical example to gain further insights. Consider a household which locates next to a coastal area into a property worth 3,000,000 dollars and which adds ten percent of this amount each year to its total value. Also, consider that the household derives amenity value equal to ten percent of the value of the property assuming that the property price capitalizes some of the amenity value. This value is also adjusted by the distance from the ocean. The hazard rate of flooding per period is constant at .05. At the assumed hazard rate, the probability of flooding will reach fifty percent in the next fifteen years. Also, assume that the household incurs a linear cost of $f$ dollars if it takes $f$ units of true information reducing effort each year. The parameter $f_1$ is assumed to be .05 which implies that if the household made no effort to reduce the true information then the probability of finding out the true information in the next 15 years would become fifty percent. The overall problem is solved by first calibrating the value functions $V_0, V_1$ and $V_2$, and then plugging these back into the optimization problem to solve for $U_1$. Note that $V_1$ is a function of the accumulated hazard rate $\lambda(t)$, therefore the optimization problem is looped over several possible values of $\lambda(t)$ and then calibrated. $V_0$ and $V_2$ are constant arguments in the optimization of $U_1$. For simplicity, assume that $V_2$ only comprises the discounted sum total of fixed per period wages and the forgone property value and amenity losses do not yield any negative utility.
Finally, also assume that the psychological cost associated with finding out true information is some fraction (say $\psi$ percent) of the expected value $A$.

Figure 1 shows the optimal value $U_1$ for several combinations of parameters $\psi$ and $\lambda(t)$. Notice that $U_1$ is declining in both these parameters. The decline however is much steeper with respect to $\lambda(t)$ than with $\psi$. Figure 2 shows the optimal relocation decision under the basic mode (developed in section 2.1) for five scenarios, where in one (scenario: subsidy=99 percent) the government provides a ninety percent insurance subsidy and in the other (scenario: S_Low=.3) it regulates so that the household is forced to relocate almost a third of the distance out of the hazard prone area. Notice that the insurance subsidy leads to a marginal inward relocation compared to the base case whereas a heightened risk of flooding (given by the scenario Lamdadot=.5) leads to the earliest exit. The restricted location scenario (S_Low=.3) follows the base case time path of relocation after a certain time. When the amenity value is reduced to being only 5% of the property value, relocation is much farther.

Figure 3 reveals the much larger insurance demand made under the insurance subsidy scheme as compared to the other scenarios. There is no insurance demanded in the high risk scenario as exit happens the earliest. Relocation restrictions also do not lead to a significant deviation from the base case as the household simply follows the optimal relocation pattern consistent with the restricted optimization. Note that insurance demand declines over time as household relocates farther out with time as risk increases.

Next, we are interested in knowing the impacts of these programs on true information reduction efforts. Figure 4 shows the true information reduction efforts. Effort reduces significantly as the hazard rate of flooding is increased. It also declines when the prior $p$ on the flooding scenario is reduced to .25. Notice however, the decline is much more significant in case of an increase in the flooding risk (given by the higher hazard rate) as compared to the case when the flooding prior declines. This is because the hazard rate is something which is directly amenable to change from true information reducing effort whereas the priors held by the household are not changeable. By investing in information avoidance effort it can postpone the arrival of true information and therefore even under a reduced prior it is still beneficial for the household to delay this information.

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15 When $s=1$, the household is assumed to completely relocate out of the coastal area.
Figure 1: Value $U_1$ as a Function of Cumulative Flooding Risk and $\psi$

Note: The psychological costs were further augmented by adding a constant term to $V_0$.
Figure 2: Time Paths of Optimal Relocation Efforts

- $S_{Low} = 0.3$
- Base Case
- Subsidy = 99 percent
- Lamdadot = 0.5
- Amenity Value = 5 percent
Figure 3: Time Paths of Optimal Insurance Efforts

Insurance (dollars)

Time

- $S_{\text{Low}} = 0.3$
- Base Case
- Subsidy=99 percent
- $\lambda_{\text{dot}} = 0.5$

Insurance efforts over time for different scenarios.
Figure 4: Time Paths of True information Reduction Efforts

- **Base Case**, Lamdadot = .1
- **Base case, Low prior (p=.25)**
- **Lamdadot=.1, Low prior (p=.25)**
4. CONCLUDING REMARKS

Emotional costs associated with information related to bad outcomes could be significant enough for people to avoid such information. The implications of this behavior have been analyzed in the psychological expected utility literature. This paper has built upon this idea to explore how such emotional costs may bear upon the self insurance and market insurance behavior of agents faced with environmental hazards. The model developed in this paper incorporates these psychological costs to explore implications for dynamic insurance and information avoidance behavior against coastal hazards. Households are found to avoid true information in order to continue enjoying the environmental amenities offered by the coastal region, however, the extent of true information avoidance varies over time and over scenarios. The costs of true information avoidance could be the direct costs associated with searching for contrary information or the emotional cost associated with adhering to a shrinking group in the society. An increase in the flooding hazard significantly reduces these efforts as the household must weigh the effectiveness of information avoidance effort against the increased possibility of a flooding hazard in the near future. A reduction in the household’s own priors over the probability of flooding does not reduce information avoidance effort as much. This is because by investing in information avoidance effort it can postpone the arrival of true information and therefore even under a reduced prior it is still beneficial to delay this information.

While the model presented in this paper attempts to integrate certain assumptions of the psychological expected utility models with self insurance and market insurance behavior, there remains further scope for explaining true information avoidance behavior when other factors such as threats of property devaluation and lack of insurance markets come into play. Another potential research application could be to try and integrate this approach with Prospect Theory. Agents may simultaneously exhibit information avoidance behavior and risk weighting or these two might dynamically evolve with the arrival of more information, with repeated experiences or through increased social interactions. Incorporating these aspects will help arrive at a better understanding over the nature of the complementarity between public incentives (or regulations) and private risk mitigation and adaptation efforts.
### Appendix: Table 1. Base Case Parameters

<table>
<thead>
<tr>
<th>$r$</th>
<th>.1</th>
<th>Discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w$</td>
<td>100,000</td>
<td>Annual wage rate in dollars</td>
</tr>
<tr>
<td>$j$</td>
<td>.05</td>
<td>Adjustment parameter for utility derived from property</td>
</tr>
<tr>
<td>$f_1$</td>
<td>.05</td>
<td>Constant component of true information hazard</td>
</tr>
<tr>
<td>$\lambda_0(t)$</td>
<td>0</td>
<td>Initial value of cumulative flooding risk hazard</td>
</tr>
<tr>
<td>$\phi_0(t)$</td>
<td>0</td>
<td>Initial value of cumulative true information revelation hazard</td>
</tr>
<tr>
<td>$\psi$</td>
<td>.1</td>
<td>Psychological cost of true information revelation as a proportion of A</td>
</tr>
<tr>
<td>$k(t)$</td>
<td>$3,000,000 \cdot (1 + r \cdot t)$</td>
<td>Property value in dollars as a function of time</td>
</tr>
<tr>
<td>$\dot{\lambda}$</td>
<td>.05</td>
<td>Hazard rate of flooding</td>
</tr>
<tr>
<td>$p$</td>
<td>.5</td>
<td>Household prior over probability of flooding risk being real</td>
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<tr>
<td>$V_2$</td>
<td>126.642</td>
<td>Optimized value of sum of utility after a flooding damage</td>
</tr>
<tr>
<td>$V_0$</td>
<td>151.022</td>
<td>Optimized value of sum of utility from not taking any protection and insurance measures until either flooding or true information are realized</td>
</tr>
<tr>
<td>$V_1$</td>
<td>$147 \cdot \exp(-\lambda(t))$</td>
<td>Optimized value of sum of utility after taking optimal protection and insurance measures upon revelation of the true information about flooding risk</td>
</tr>
</tbody>
</table>
REFERENCES


