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Information and Collective Risk Reduction

by

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Risk

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ABSTRACT

Information and nonincreasing absolute risk aversion have been shown to decrease voluntary contributions to traditionally defined public goods. This paper explores whether this result holds for public goods in the form of collective risk reduction programs. Risk differs from traditional public goods in that risk is comprised of two core elements: probability and severity. We find that the impact of information on voluntary contributions now depend on the convexity of the marginal severity function and risk aversion. For probability reduction, risk aversion no longer solely motivates behavior, the convexity of the marginal probability function is the driving force (a measure of aversion to productivity uncertainty). Our results suggest that any policy promoting voluntary provision of collective risk reduction through information will confront complexities which may render the effort ineffective.

1. Introduction

During the past decade we have witnessed the growing trend to deregulate private industry and to decentralize public projects [see Peltzman's (1989) review]. Public projects aimed at reducing environmental risk have not been exempt from this trend. The decentralization of risk reduction has focused primarily on hazard warnings and private self-protection as regulatory alternatives [e.g., Johnson (1989), Viscusi (1989)]. Self-protection is appealing since it reflects the principle of respect for individual autonomy. The informed individual selects the efficient level of protection based on personal risk preferences.

Aside from noted problems with risk misperception,[1] self-protection can be economically inefficient due to scale economies. The Chernobyl nuclear accident, for example, was a large scale disaster that did not create much opportunity for efficient provision of private protection. Although individuals ingested iodine tablets, most risk reduction efforts were too expensive or complicated to be individually efficient. Collective relief efforts were necessary to both directly reduce risk of illness and to inform individuals of the limited self-protection opportunities that were available.

Assuming we are committed to decentralized risk reduction even if private self-protection is inefficient, then one alternative is to promote voluntary contributions to collective risk reduction programs. The major problem with any voluntary provision of a collective good is the classic free rider problem [Wicksell (1896)]. A rational, self-interested individual may withhold private information on his preferences for the good and will free ride off the contributions of others, thereby providing a socially inefficient contribution. As shown by Austen-Smith (1980), however, the perfectly plausible assumption that each individual is uncertain as to the exact level of the collective good forthcoming can induce the risk averse individual to increase his voluntary contributions [also see Sandler et al. (1987) and Shogren (1987)]. While perhaps not completely eliminating free riding, altering information given nonincreasing absolute risk aversion can increase voluntary contributions to public goods.

This paper explores whether information will have the same effect on voluntary contributions to collective risk reduction programs. We find the answer is now more complicated. Risk is defined by two elements: probability and severity.[2] Voluntary contributions to collective risk reduction programs can be designed to reduce either element [Ehrlich and Becker (1972)]. To illustrate how information influences collective risk reduction, a 2 x 2 classification of information is considered. Good news and bad news information implies the mean level of the publicness of other individuals contributions is increasing or decreasing. Sharper or diffuse information implies the variance associated with publicness is decreasing or increasing.

We find that increased sharper good news will unambiguously decrease voluntary contributions to a collective program that reduces the severity of a risk given two conditions: nonincreasing absolute risk aversion and a weakly concave marginal severity function. Consequently, the release of information which more precisely indicates a higher level of total contributions will accentuate free riding behavior. Alternatively, a policy that increases diffuse bad news will ameliorate free riding.

In contrast, the impact of information on the collective reduction of the probability of the risk is generally ambiguous. A sufficient condition for sharper good news to decreased free riding is if the individual's marginal probability function is weakly convex and if aversion to production uncertainty outweighs risk aversion. Note that risk aversion does not have to directly enter into the individual's decision for information to have an impact.

The main conclusion is that the innocuous assumption of risk aversion is no longer sufficient to guarantee increased voluntary contributions given collective risk reduction. Voluntary contributions to collective risk reduction programs are influenced by a more complex relationship than traditional public goods. Any policy promoting voluntary collective risk reduction will confront a knotty environment. For example, sharper good news increases free riding for severity reduction, but can decrease free riding for probability reduction. Since identical information can be interpreted differently by different individuals, information-based policy recommendations need to address both how risk is reduced and how information impacts the moments of the distribution.

2. Voluntary Contributions to Collective Risk Reduction

2.1. Assumptions

Consider a Nash-Cournot economy where a representative risk averse individual j is selected from a group size n. Let $1-\pi$ and π represent the individual's subjective probability that he will and will not be exposed to an undesired state of nature: a monetary loss of severity L.[3] The individual has a thrice differentiable, continuous, and monotonic increasing state independent von Neumann-Morgenstern utility index, U, defined over wealth. Let $U_1 = U(M)$ and $U_2 = U(M-L)$ represent the utility of the desired and undesired state of nature, where M is monetary income. Without risk reduction, the two mutually exclusive and jointly exhaustive states defining the individual's expected utility are

$$EU = \pi U(M) + (1-\pi)U(M-L).$$

Assuming inefficient private self-protection, the individual can reduce the risk by voluntarily contributing to a collective program to decrease the probability $(1-\pi(X))$ or severity $(L(Z))$ of the undesired state. Following Nitzan and Slutsky (1988), let $X = x_j + ß\Sigma x_i$ and $Z = z_j + ß\sum_i z_i$ $(i \neq j)$ represent total contributions to reduce the probability and severity of the undesired state, where x_j and z_j is the individual's voluntary contribution and Σx_i and Σz_i $(i \neq j)$ is the total level of all other individuals (n-1) contributions. The degree of publicness of other individual's contributions is represented by ß $(0 \leq ß \leq 1)$, and is assumed uncertain to the individual. Let $G(ß;\alpha)$ be the individual's subjective distribution of ß defined over the support [a,b]. As $ß \rightarrow 0$, then other individual's contributions are perceived as strictly private; $ß \rightarrow 1$ implies strictly collective goods; and $ß > 1$ implies the individual overestimates the publicness of the good.

2.2. Good News and Bad News Information

It is well recognized that individual's often misperceive risk [see Machina (1982), Viscusi (1989)]. One documented factor which influences this phenomena is the individual's perceived control over the risk [Perlmuter and Monty (1979)]. The individual's misperception of risk increases as the perceived control changes. In the case of voluntary contributions, the key factor in the individual's perceived control is the degree of publicness of other individual's contributions, ß. How an individual perceives the degree of publicness is an information problem. Let α be the index of information defined by a second-order stochastic dominant shift in the distribution.

Define a second-order shift that changes information by a mean and variance effect

$$\int_a^b G_\alpha d\text{ß} \gtreqless 0 \text{ and } \int_a^{\text{ß}} G_\alpha(K;\cdot)dK \gtreqless 0.$$

We classify information as a 2 x 2 design based on the mean and variance effects. The mean effect is defined as either good news or bad news. Define good news as the increase in the mean level of the publicness, ß. Bad news implies the opposite. Define the variance effect as being sharper (diffuse) news if information decreases (increases) the variance associated with ß. Figure 1 illustrates the 2 x 2 classification. Sharper good (bad) news implies the individual becomes more certain that there is a higher (lower) degree of publicness of the others' individuals contributions. Diffuse bad (good) news implies less certainty that there is a lower (higher) level of publicness. Note we allow sharper good news and diffuse bad news to include the cases where either the mean or variance effect equals zero, but not both.

3. Severity and Information

First consider the representative individual's voluntary contributions to a collective program to reduce the severity of the risk. The individual selects z_j to maximize expected utility

$$\underset{z_j}{\text{MAX}} \int_a^b [\pi U(M-z_j) + (1-\pi)U(M-L(z_j + \text{ß}\sum_{i\neq j} z_i) - z_j)]dG(\text{ß};\alpha).$$

First- and second-order conditions for an interior solution are

$$-\pi U_1' - (1-\pi)\int_a^b U_2'(L' + 1)dG(\cdot) = 0 \qquad (1)$$

$$\Gamma = \pi U_1'' + (1-\pi)\int_a^b [U_2''(L' + 1)^2 - U_2'L'']dG(\cdot) < 0 \qquad (2)$$

Assume $U_1' > 0$, $U_2' > 0$, $U_1'' \leq 0$, $U_2'' \leq 0$, $U_2''' \geq 0$, $L' < 0$ and $L'' > 0$, where primes denote partial derivatives. Nonincreasing absolute risk aversion is assumed ($U'''_2 \geq 0$); the individual becomes less risk averse as he acquires more of the good subject to the absolute risk [Pratt (1964)]. Note $|L'| > 1$ is required for an interior solution. Assume (2) holds whenever (1) holds.

The Nash equilibrium is determined by assuming identical individuals such that $z_j = z_i$ in equation (1). The equilibrium value z* satisfies

$$-\pi U_1'(M-z^*) - (1-\pi)\int_a^b [U_2'(M-L((1+(n-1)\beta)z^*) - z^*)(L'((1+(n-1)\beta)z^*) + 1)]dG(\cdot) = 0. \qquad (3)$$

To determine the impact of a change in information on the equilibrium value of z* take the first-order condition (3), apply the implicit function theorem, then integrate by parts twice to obtain

$$\frac{\partial z^*}{\partial \alpha} = \frac{(1-\pi)((n-1)z^*)^2}{\Gamma}\left[(U_2''L'(L'+1) - U_2'L'')\int_a^b G_\alpha d\beta \right.$$
$$\left. - \int_a^b\left\{\int_a^\beta G_\alpha(K;\cdot)dK\right\}\left[-U_2'''(L')^2(L'+1) + U_2''L''(3L'+1) - U_2'L'''\right]d\beta \right] \qquad (4)$$

The first term in brackets on the right-hand side of (4) is the mean effect; the second term is the variance effect. Given $U'' \leq 0$ and $L'' > 0$ by assumption, the sign of the mean effect depends solely on the type of information provided, good or bad news. The sign of the variance effect is more complicated. Besides having to know whether the information is sharper or diffuse, one also has to know the convexity of the marginal utility and severity functions. The sign of the variance effect will depend solely on the type of information given two conditions are fulfilled: weakly convex marginal utility function ($U''' \geq 0$) and a weakly concave marginal severity function ($L''' \leq 0$). The utility condition is fulfilled by assuming nonincreasing absolute risk aversion. Several standard damage functions satisfy the weak concavity requirement. Linear or quadratic functions yield weak concavity, i.e., $L''' = 0$. A rectangular hyperbola (e.g., $L = 1/x$), logarithmic or exponential damage function implies strictly concavity, i.e., $L''' < 0$. Therefore, the requirement is satisfied for a broad range of damage functions, and is less restrictive than may appear at first glance.

The following proposition summarizes the impact of information on voluntary contributions to severity reduction.

Proposition 1: An increase in sharper good news (diffuse bad news) regarding the publicness of other individual's contributions will decrease (increase) the equilibrium level of voluntary contributions to a public program reducing the severity of a risk if the individual exhibits nonincreasing absolute risk aversion and if the marginal severity function is weakly concave.

Free riding increases if there is an increase in sharper good news. Providing information is often mandated in matters of risk and safety where there are "right-to-know" laws. By providing sharper good news one actually creates an incentive to decrease voluntary contributions, thereby increasing public risk. In contrast, providing diffuse bad news reduces an individual's confidence in assuming a high degree of publicness. This information decreases free riding. An individual is now willing to contribute more given he is less certain as to the total collective effect. His actions are now aimed at increasing loss reduction actions since he can no longer rely on the actions of other individuals.

With the cases of sharper bad news or diffuse good news, the impacts on voluntary contributions is more complicated. Now the mean and variance effects have countervailing impacts. Sharper information reduces uncertainty which tends to increase free riding, but the bad news implies lower collective protection thereby reducing free riding. Whether the magnitude of the mean or variance term dominates the other is unknown at this point. However, without knowing which term dominates it becomes difficult to offer a blanket recommendation on how an information program will impact voluntary contributions to collective severity reduction. More careful examination of how information impacts an individual's perception of the first two moments of the distribution will be required to anticipate behavioral response. Corallary 1 summarizes our observations.

Corollary 1. An increase in sharper bad news will increase (decrease/have no effect on) voluntary contributions if the mean effects exceed (is less than/equals) the variance effect. An increase in diffuse good news will increase (decrease/have no effect on) voluntary contributions if the variance effect exceeds (is less than/equals) the mean effect.

4. Probability and Information

Assume the individual is now given a chance to reduce the risk by voluntarily contributing to a program to reduce the probability of the undesired state. The individual then selects x_j to maximize expected utility

$$\underset{x_j}{\text{MAX}} \left[\int_a^b [\pi(x_j+\beta\Sigma x_i)U(M-x_j)+(1-\pi(\cdot))U(M-L-x_j)]dG(\beta;\alpha)\right]. \quad (i\neq j)$$

First- and second-order conditions for an interior solution at a maximum are

$$\int_a^b [\pi' V - \pi U_1' - (1-\pi)U_2']dG(\cdot) = 0 \qquad (4)$$

$$\Phi = \int_a^b [\pi'' V + 2\pi'[U_2'-U_1'] + \pi U_1'' + (1-\pi)U_2'']dG(\cdot) < 0.$$

Assume $\pi' > 0$, and $\pi'' < 0$, and let $V = U_1 - U_2 > 0$.

Assuming identical individuals ($x_j = x_i$), the Nash equilibrium value x* satisfies

$$\int_a^b [\pi'((1+(n-1)\beta)x^*)V^* - \pi((1+(n-1)\beta)x^*)U'_1(M-x^*)$$

$$- (1-\pi(\cdot))U'_2(M-L-x^*)]dG(\cdot) = 0, \qquad (5)$$

where $V^* = U_1(M-x^*) - U_2(M-L-x^*)$.

To determine the impact of information on the equilibrium value of x*, take the first-order condition (2), apply the implicit function theorem, then integrate by parts twice yielding

$$\frac{\partial x^*}{\partial \alpha} = \frac{((n-1)x^*)^2}{\Phi} \left[\left[\pi' \int_a^b G_\alpha d\beta - \int_a^b \left\{ \int_a^\beta G_\alpha(K;\cdot)dK \right\} \pi'' d\beta \right] \left[U_1'^* - U_2'^* \right] \right.$$

$$\left. - V^* \left[\pi'' \int_a^b G_\alpha d\beta - \int_a^b \left\{ \int_a^\beta G_\alpha(K;\cdot)dK \right\} \pi''' d\beta \right] \right] . \qquad (6)$$

Given the assumptions of the model, the sign of equation (6) is ambiguous. The first set of terms in brackets is the direct utility effect of risk aversion ($U_2' \geq U_1'$) weighted by the mean effect, $\int G_\alpha d\beta$. As shown in Austen-Smith (1980), the standard assumption of nonincreasing absolute risk aversion is usually sufficient to determine the impact of information in voluntary contributions. However, in this case it is not. The second set of terms in brackets is the indirect utility effect of protection, and is generally ambiguous.

To further define the relationship between the direct and indirect effects rewrite (6) as

$$\frac{\partial x^*}{\partial \alpha} = \frac{\theta V^*((n-1)x^*)^2}{\Phi} \left[IR(\beta) - R(\beta)\right] \tag{7}$$

$$\text{where} \quad \theta = \pi' \int_a^b G_\alpha d\beta - \int_a^b \left\{ \int_a^\beta G_\alpha dk \right\} \pi'' d\beta \tag{8}$$

$$R(\beta) = - [U_1'^* - U_2'^*]/V^* \geq 0 \tag{9}$$

$$IR(\beta) = - \left[\pi'' \int_a^b G_\alpha d\beta - \int_a^b \left\{ \int_a^\beta G_\alpha dk \right\} \pi''' d\beta \right] / \theta \tag{10}$$

R(ß) is the first-order approximation of the Arrow-Pratt absolute risk aversion index. IR(ß) can be interpreted as a measure of absolute aversion to production uncertainty determined by the curvature of the probability function. Shogren (1990a) demonstrates that π''' is positive provided an individual's willingness to pay a premium to learn his productivity decreases as the probability of the desired state increases. The proof is analogous to the Arrow-Pratt definition [see Shogren (1990a) for details].

Assuming nonincreasing aversion to production uncertainty, a sufficient condition for decreased free riding given increased information is if the individual is risk neutral, $U_1'^* = U_2'^*$, then R(ß) equals zero and disappears from (7). Proposition 2 summarizes the impact of information on voluntary contributions to reduce the probability.

<u>Proposition 2</u>: An increase in sharper good news (diffuse bad news) regarding the publicness of other individual's contributions will increase (decrease) the equilibrium level of voluntary contributions to a public program which reduces the probability of a risk given nonincreasing absolute aversion to production uncertainty ($\pi''' \geq 0$) and risk neutrality.

Assuming risk neutrality, sharper good news ameliorates free riding. This result directly contrasts severity reduction where sharper good news increases free riding. Depending on how the risk is reduced, identical information can create opposite behaviorial reactions. The risk reduction mechanism matters in information policy. How a risk is reduced, either altering the probability or severity, will influence how effective information is at increasing voluntary contributions to collective risk reduction.

If we assume risk aversion, however, the impact of information becomes more complicated. Providing sharper good news will increase contributions if and only if the aversion to production uncertainty outweighs risk aversion. Otherwise, the information will cause more free riding. Likewise, increased diffuse bad news will result in decreased free riding. More research is needed to explore the relative magnitudes of the two countervailing impacts. Until then, policies which promote information strategies to influence collective contributions face an uncertain behavioral environment in which the type of information may have unintended impacts.[4]

5. Conclusion

Voluntary contributions to collective risk reduction programs can be influenced by information. However, the degree of influence depends crucially on the risk reduction mechanism. If risk is reduced by altering the severity of the undesired event, then the provision of sharper good news will increase free riding behavior provided the individual exhibits nonincreasing absolute risk averse and the marginal severity function is weakly concave. Alternatively, free riding declines for severity risk reduction if the level of diffuse bed news increases.

If risk is reduced by changing the probability of the undesired event, then the results are less certain. In contrast to severity reduction, a sufficient condition for reduced free riding is to increase sharper good news provided aversion to production uncertainty outweighs risk aversion.

As of now no true policy exists promoting voluntary provision of collective risk reduction. Our results suggest the complexity of risk reduction does not automatically lend itself well to an information policy approach (e.g., risk communication, contingent valuation). For example, an increase in sharper good news increases free riding for severity reduction but decreases free riding for probability reduction. Such results suggest that increasing our understanding of the interaction between information and risk reduction is vital for more effective policy promoting public safety.

NOTES

1. Misperception of risky events include overestimation of low probability events, the common consequence effect, the common ratio effect, and the utility evaluation effect. See Machina (1982) for an excellent overview of this literature.

2. Current work on the reduction of environmental risk has focused primarily on the reducing of probability of the undesired state of nature [see for example Smith and Desvousges (1987)]. Work by Shogren (1990b), however, suggests that individuals value reductions in probability significantly different than reductions in severity.

3. Assume moral hazard prevents the individual from acquiring full insurance coverage from the undesired state.

4. Sharper bad news and diffuse good news have an ambiguous impact on IR(ß). The mean and variance effects have opposite impacts. Without a priori data, one cannot say which term will dominate the other. Consequently, these two types of information cannot be ruled out as having adverse impacts on free riding behavior.

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Variance Effect	Mean Effect: Negative	Mean Effect: Positive
Negative	Sharper Good News	Sharper Bad News
Positive	Diffuse Good News	Diffuse Bad News

Figure 1. Information structure