On Correlation Aversion and Insurance Demand

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Abstract: This is a study of decision problems under two-dimensional risk. We use an existing index of absolute correlation aversion to conveniently classify bivariate preferences, with respect to attitudes toward this risk. This classification seems to be more important than whether decision makers are correlation-averse or correlation-seeking for the study of insurance demand when a loss has a multidimensional impact. On this note, we also re-examine Mossin’s theorem under bivariate preferences, where full insurance is preferred with a fair premium, while less than full coverage is preferred with a proportional premium loading. Furthermore, based on the comparative statics of this two-dimensional insurance model for changes in correlation aversion, we derive testable implications about the classification of bivariate utility functions. For the particular case when the two-dimensional risk can be interpreted as risk on income and health, we identify the form of separable utility functions depending on health status and income that is consistent with household disability insurance decisions.

Keywords: correlation aversion; disability insurance; health; decision making under uncertainty; two-dimensional risk; tradeoffs between income and health

JEL Classification: D81; G52; I1; R22

1. Introduction

The notion of risk aversion has played a key role in the research of financial economics. There are many equivalent ways to define risk aversion that could also be related to the propensity to purchase full insurance at an actuarially fair price. In his seminal work on the theory of insurance demand, Mossin (1968) shows the important role of the index of absolute risk aversion and proves that insurance is an inferior good if the decision maker has a utility function with one attribute that exhibits decreasing absolute risk aversion. The analysis of most insurance decision problems depends entirely on the characterization of the utility regarding the index of absolute risk aversion (Bodily and Furman 2016; Lee 2012). However, decisions are often multidimensional. For instance, many medical and financial decisions depend on both wealth and health status (Attema et al. 2019).

Comparisons of bivariate distributions have been discussed in various frameworks. The concept of correlation aversion is a generalization of risk aversion to bivariate utility functions. Crainich et al. (2017) develop an index for absolute correlation aversion by assuming, without loss of generality, that the first attribute is subject to a monetary payment while the second attribute is nonpecuniary. A similar index has been suggested by Gollier (2020) in a different setting. We first use this index to classify preferences on two-dimensional risk. Gollier (2003) mentions that consumers face several sources of risk, some of which are uninsurable. Also, there are cases where one source of risk impacts various aspects of well-being, such as wealth and health. A good example is disability insurance.
The literature examines basic principles of insurance demand in various frameworks that differ from ours in many aspects (Chi and Wei 2020; Hinck and Steinorth 2023; Hong et al. 2011; Picard 2016; Rey 2003). Based on Mossin’s theorem, in a one-period setting, individuals prefer full insurance with a fair premium, while less coverage is preferred with a proportional premium loading. One of our contributions is to reexamine Mossin’s theorem in a bivariate setting where one common source of risk impacts various aspects of individual well-being. We also prove a refinement of Mossin’s theorem by utilizing the index of correlation aversion.

Grossman (1972) introduces a general form of preferences depending on the stock of health per period. Following the introduction of Grossman’s model on the demand for health, a plethora of papers have reported on the investigation of the period utility function of wealth and health, both empirically and theoretically (Rey and Rochet 2004; Viscusi and Evans 1990). The literature is crucial for the subsequent cost-effectiveness and cost-benefit analysis (Bleichrodt and Quiggin 1999). Many papers highlight the need for an investigation of the effect of health on the marginal utility of income within an insurance demand framework (Brown and Finkelstein 2009).

We also contribute to the strand of literature in the form of preferences. We show how the insurance demand findings in a bivariate setting can be used to improve our understanding of the form of preferences in income and health. These preferences should have features that do not contradict observed behaviors. We use empirical evidence on observed household behavior from national survey data, as presented in the literature. We specifically discuss how our framework has some implications for disability insurance, a type of insurance that has received poor attention in the literature compared to other types of labor income insurance, such as unemployment (Low and Pistaferri 2020). We propose utility functions that exhibit increasing absolute correlation aversion in the context of private disability insurance.

A disability event would significantly impact many aspects of the well-being of a household (Ipék 2020; Kalenkoski and Pabilonia 2023). Pitthan and Witte (2021) emphasize that the studies in the existing literature are not able to provide competent explanations for the underinsurance of risks with high consequences. In the context of disability insurance, the presence of public policies can instill a sense of reassurance within households, fostering the belief that any financial setbacks resulting from disability would be mitigated to a certain extent. Consequently, the public insurance’s presence may limit demand for private disability policies (Brown and Finkelstein 2009). Indeed, disability insurance is less popular than the other types of insurance plans. Only one-third of the workers in the United States are covered by private long-term disability insurance (Autor et al. 2014). The probability of a 35-year-old in good health encountering a disability prior to reaching retirement age is approximately twenty-five percent (Carroll et al. 2022). As Carroll et al. (2023) report, the risk of becoming disabled outweighs the risk of being in a car accident. Private disability offers benefits through in-work assistance, so work limitations are not career-ending disabilities (Autor et al. 2019). Moreover, another form of disability coverage exists, known as short-term disability insurance. Individuals covered under short-term disability insurance can access its benefits if they are unable to work due to illness or disability for a duration exceeding their available sick days, typically set at around 90 days. This provision can significantly bolster an individual’s income, which becomes particularly crucial during periods such as the recent COVID-19 pandemic. Although COVID-19 symptoms are usually of short duration, some adults experience persistent symptoms that last for months or years, which is known as long COVID (O’Mahoney et al. 2023).

Section 2 classifies the utility functions with respect to the index of absolute correlation aversion and sets the theoretical insurance framework. Section 3 examines the standard results of insurance demand in the literature within our insurance framework and presents a refinement of Mossin’s theorem. Section 4 examines how the properties of the utility functions regarding the absolute correlation aversion index play an important role in the discussion about preferences on income and health. This study focuses on the case of
disability insurance. We address the question of which form of preferences best fit the observed household behaviors. Section 4 provides the concluding remarks.

2. Materials and Methods

Richard (1975) showed that a correlation-averse (seeking) decision maker has a utility function \( U(x, y) \) with \( U_{12}(x, y) = \frac{\partial^2 U(x, y)}{\partial x \partial y} < (>)0 \) that is the property of twice differentiable utility functions that meet Equation (1). Equation (1) below is considered the standard definition of submodular (supermodular) functions:

\[
U(x_1, y_1) + U(x_0, y_0) < (>) U(x_1, y_0) + U(x_0, y_1) \text{ where } x_0 < x_1 \text{ and } y_0 < y_1 \quad (1)
\]

Consider a decision maker with utility function \( U(x, y) \) and endowed with \((x_1, y_1)\) who faces two binary lotteries A and B. Lottery A gives the decision maker a 50% probability of no loss for both attributes, and a 50% probability of observing a loss of \( l_x \) from the first attribute only, with probability 50%, or a chance of losing \( l_y \) from the second attribute only, with the same probability of 50%. If \( l_x = x_1 - x_0 \) and \( l_y = y_1 - y_0 \) denote the losses for the first and second attribute, respectively, based on (1), Richard (1975) proved that a correlation-averse decision maker would prefer lottery A (with two perfectly negative correlated losses), than lottery B (with two perfectly positive correlated losses). Rey (2003) discusses the importance of correlation between risks and the sign of the utility function’s cross-derivative regarding insurance decisions.

Crainich et al. (2017) define the index of absolute correlation aversion as \( C(x, y) = \frac{-U_{12}(x, y)}{U_{11}(x, y)} \), where \( y \) is a nonpecuniary attribute. This index parallels the standard coefficient of absolute risk aversion in the Arrow–Pratt sense (Crainich et al. 2017; Picard 2016). Based on this index \( C(x, y) \), preferences can be ranked with respect to the intensity of absolute correlation aversion (submodularity). Collier (2020) also proposes, in a different setting, the fraction \( \frac{U_{12}(x, y)}{U_{11}(x, y)} \) as the index for absolute correlation-seeking (supermodularity).

The introduction of such an index of absolute correlation aversion allows the classification of preferences contingent on the properties of function \( C(x, y) \). To the best of our knowledge, this is the first time that preferences are classified with respect to the absolute correlation aversion index. Specifically, we classify preferences as follows:

**Definition 1.** Bivariate preferences are said to exhibit decreasing absolute correlation aversion (DACA) if \( C(x, y) \) is not increasing in both \( x \) and \( y \), and is at least non-constant in one of the two variables. Similarly, bivariate preferences exhibit increasing absolute correlation aversion (IACA) if \( C(x, y) \) is not decreasing in both \( x \) and \( y \), and is at least non-constant in one of the two variables. Finally, bivariate preferences exhibit constant absolute correlation aversion (CACA) if \( C(x, y) \) is constant in both \( x \) and \( y \).

Under the assumption of three times differentiable utility functions, the definition of DACA (IACA) preferences can be expressed as the following three conditions:

\[
\frac{\partial C(x, y)}{\partial x} \leq (>)0 \\
\frac{\partial C(x, y)}{\partial y} \leq (>)0 \\
\frac{\partial C(x, y)}{\partial x} + \frac{\partial C(x, y)}{\partial y} < (>)0
\]

The above inequalities can be written as follows:

\[
\frac{\partial C(x, y)}{\partial x} \leq (>)0 \iff C(x, y)A(x, y) \leq (>)P_H(x, y)
\]
We assume that \( \lambda \) with high consequences, which we discuss in the following sections. We now present how \( A \) variable \( \lambda \) the above expression will be negative for utility function \( U \) bivariate setting, for an additive separable (Picard 2016; Rey and Rochet 2004) concave for a decision maker who is risk-averse, with respect to variable \( x \) of high highlights that there are various uninsurable sources of risk. We observe that, as a function considered in the sense that there is no coverage for the second attribute. Gollier (2003) unusually assumption (Schlesinger 2013), especially for types of insurance that are about risks causes a decreased physical capacity for work causes a decrease in income. We follow a setting similar to Eling et al. (2021). Suppose an insurer offers a coinsurance contract with a fixed proportion paid by the insurer. The premium is an indemnity schedule in which the insurer pays a fixed proportion of the monetary loss of the first attribute. The indemnity payment is given by the function \( \alpha \) initial level \( x \), \( y \), and \( C \) called the coinsurance rate and is the fixed proportion paid by the insurer. The premium \( P \) is then given by \( P(\alpha) = \alpha(1 + \lambda)E\tilde{x} \), where \( \lambda \) is the loading factor demanded by the insurer. We assume that \( \lambda \) is nonnegative, and no full or over insurance is offered. This is not an unusual assumption (Schlesinger 2013), especially for types of insurance that are about risks with high consequences, which we discuss in the following sections. We now present how the classification of utility functions presented in Definition 1 can help us better understand the demand for insurance.

3. Results

We first re-examine Mossin’s theorem within this insurance framework of incomplete markets where the risk has a multidimensional impact. The incomplete market is considered in the sense that there is no coverage for the second attribute. Gollier (2003) highlights that there are various uninsurable sources of risk. We observe that, as a function of \( \alpha \), the final level \( x \) is given by \( x(\alpha, \tilde{x}) = X - \alpha(1 + \lambda)E\tilde{x} - \tilde{x} + a\tilde{x} \), and the final level \( y \) is given by \( y(\tilde{x}) = Y - \tilde{y} = Y - h(\tilde{x}) \). When \( \lambda = 0 \), full insurance (\( \alpha = 1 \)) is optimal for a decision maker who is risk-averse, with respect to variable \( x \) (Mossin 1968). In the bivariate setting, for an additive separable (Picard 2016; Rey and Rochet 2004) concave utility function \( U(x, y) \):

\[
\frac{\partial C(x, y)}{\partial y} \leq (\geq)0 \iff C^2(x, y) \leq (\geq)P_W(x, y)
\]

\[
\frac{\partial C(x, y)}{\partial x} + \frac{\partial C(x, y)}{\partial y} < (>)0 \iff C(x, y)(C(x, y) + A(x, y)) < (>)P_W(x, y) + P_H(x, y)
\]

where \( A(x, y) = -\frac{U_{11}(x, y)}{U_{1}(x, y)} \) is the absolute risk-aversion coefficient, while \( P_H(x, y) = \frac{U_{12}(x, y)}{U_{1}(x, y)} \) and \( P_W(x, y) = \frac{U_{12}(x, y)}{U_{1}(x, y)} \) is the measure of cross-prudence (Crainich et al. 2017; Eeckhoudt et al. 2007; Macé 2015). For example, preferences that exhibit cross-imprudence in both attributes\(^4\) and that are correlation- and risk-averse always meet the above conditions for IACA. Finkelstein et al. (2009) review the literature on the tradeoffs between the two attributes of a bivariate utility function that represent health and income, and they highlight the need for an investigation of the effect of health on the marginal utility of income within an insurance demand framework.

Next, we develop an insurance model of a decision maker with a twice differentiable utility function \( U(x, y) \). Suppose now that the decision-maker is endowed with an \( x = X \geq 0 \), and \( y = Y \geq 0 \) while facing a random loss denoted by \( (x, y) \). Let the random variable \( \tilde{y} \) denote the decrease in initial level \( Y \), while \( \tilde{x} \) denotes the monetary loss of the initial level \( X \). There is a common source of risk that affects both variables, in the sense that for variables \( \tilde{x} \) and \( \tilde{y} \), which follow a distribution with support \([0, \tilde{x}] \times [0, \tilde{y}]\), there is a strictly increasing function \( h(\cdot) \) to model their relation, as discussed later. This assumption can definitely be considered in the case of causality for the two losses, where a decrease in \( \tilde{y} \) causes the decrease in \( \tilde{x} \) or vice versa. For example, a partial or full disability that causes a decreased physical capacity for work causes a decrease in income. We follow a setting similar to Eling et al. (2021). Suppose an insurer offers a coinsurance contract with an indemnity schedule in which the insurer pays a fixed proportion of the monetary loss of the first attribute. The indemnity payment is given by the function \( h(\cdot) \). The parameter \( \alpha \) is called the coinsurance rate and is the fixed proportion paid by the insurer. The premium \( P \) is then given by \( P(\alpha) = \alpha(1 + \lambda)E\tilde{x} \), where \( \lambda \) is the loading factor demanded by the insurer. We assume that \( \lambda \) is nonnegative, and no full or over insurance is offered. This is not an unusual assumption (Schlesinger 2013), especially for types of insurance that are about risks with high consequences, which we discuss in the following sections. We now present how the classification of utility functions presented in Definition 1 can help us better understand the demand for insurance.

Based on the assumption that \( U_1(x, y) > 0 \), \( \forall (x, y) \) and constant in the second variable, the above expression will be negative for \( \lambda > 0 \). Hence, full insurance is optimal only when \( \lambda = 0 \) for individuals who are risk-averse with respect to the first variable\(^5\).
Without any specific assumptions for the form of the concave utility function \( U(x, y) \), we observe that:

\[
\frac{\partial \text{EU}(x, y)}{\partial \alpha} \bigg|_{\alpha=0} = \int_0^X U_1 \left( X - \tilde{x}, Y - (1+\lambda)\bar{E} \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x}
\]

\[
= E \left[ U_1 \left( X - \tilde{x}, Y - h(\tilde{x}) \right) \right] - (1+\lambda)E \left[ U_1 \left( X - \tilde{x}, Y - h(\tilde{x}) \right) \right] \bar{E}
\]

\[
= \text{Cov} \left( U_1 \left( X - \tilde{x}, Y - h(\tilde{x}) \right), \tilde{x} \right) - \lambda \bar{E} E \left( U_1 \left( X - \tilde{x}, Y - h(\tilde{x}) \right) \right)
\]

(5)

Thus for \( \lambda \geq \frac{\text{Cov} \left( U_1 \left( X - \tilde{x}, Y - h(\tilde{x}) \right), \tilde{x} \right)}{E x \bar{E} U_1 \left( X - \tilde{x}, Y - h(\tilde{x}) \right)} \), no insurance is optimal.

Based on properties of the utility function, such as the concavity of \( \frac{\partial \text{EU}(x, y)}{\partial \alpha} \) in \( \alpha \), or the restrictions of no full and over insurance, for \( \lambda > 0 \), there exists \( \alpha < 1 \) that the decision maker would choose. The following Proposition 1 can be considered as a refinement of Mossin’s generalized theorem for preferences with two attributes subject to a common source of risk. We can see how the property of preferences, with respect to aversion to correlation, determines the optimal level of partial coinsurance. Thus, we consider the case where \( \lambda > 0 \) and \( 0 < \alpha < 1 \) and prove the following proposition within the framework presented in the previous section without any assumptions regarding the form of the utility function \( U(x, y) \):

**Proposition 1.** For a common source of risk in both attributes, an increase in the initial level of \( Y \) will decrease (increase/not affect) the optimal level of insurance under DACA (IACA/CACA) preferences.

**Proof.** Assume a utility function \( U(x, y) \) that exhibits DACA. A decision maker chooses a coinsurance rate \( \alpha \) to maximize expected utility, \( EU(x, y) \). Let \( \alpha^* \) be the optimal insurance.

We observe that:

\[
\frac{\partial \text{EU}(x, y)}{\partial \alpha} \bigg|_{\alpha^*} = -\int_0^X C(x, y) U_1 (x, y) \left( \tilde{x} - (1+\lambda)\bar{E} \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x}
\]

Denote \( x_0 = x(\alpha^*, \bar{x}_0) \), and \( y_0 = y(\bar{x}_0) \), where \( \bar{x}_0 = (1+\lambda)\bar{E} \).

Since

\[
-\int_0^{\bar{x}_0} C(x, y) U_1 (x, y) \left( \tilde{x} - \bar{x}_0 \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x} < -\int_0^{\bar{x}_0} C(x_0, y_0) U_1 (x, y) \left( \tilde{x} - \bar{x}_0 \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x}
\]

and

\[
-\int_{\bar{x}_0}^X C(x, y) U_1 (x, y) \left( \tilde{x} - \bar{x}_0 \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x} < -\int_{\bar{x}_0}^X C(x_0, y_0) U_1 (x, y) \left( \tilde{x} - \bar{x}_0 \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x}
\]

then,

\[
\frac{\partial \text{EU}(x, y)}{\partial \alpha} \bigg|_{\alpha^*} < -C(x_0, y_0) \int_0^X U_1 (x, y) \left( \tilde{x} - \bar{x}_0 \right) f_{\tilde{x}}(\tilde{x}) d\tilde{x} = 0
\]

(6)

Thus, an increase in the initial level of \( Y \) will decrease \( \alpha^* \). This is a direct result from the above inequality and the second order condition where \( \frac{\partial \text{EU}(x, y)}{\partial \alpha} \) is decreasing around \( \alpha^* \).

Suppose that \( \alpha^*_1 \) is the optimal insurance for an initial level \( Y = Y_1 \).

For an increase in the initial level of \( y \), from \( Y_1 \) to \( Y_2 \), we show that \( \frac{\partial \text{EU}(x, y)}{\partial \alpha} \bigg|_{\alpha^*_1} < 0 \).

Since \( \frac{\partial \text{EU}(x, y)}{\partial \alpha} \) is decreasing in \( \alpha \), the new optimal insurance is a value \( \alpha^*_2 < \alpha^*_1 \).

The statements for IACA and CACA can be proved in a similar manner. □

These results for insurance demand, within the framework of a common source of risk in incomplete markets, are proved without making assumptions about what aspects
of well-being the two attributes can represent. Insurance demand results and Mossin’s theorem are studied in different theoretical settings in the literature without empirical testing (Chi and Wei 2020; Hong et al. 2011; Picard 2016). However, Eling et al. (2021) emphasize that the empirical results for the link between risk attitudes and the demand for various types of insurance are inconsistent. Most household surveys include only univariate risk-aversion questions. Our findings can be empirically tested by examining various cases of bivariate risk to see if there is a significant association between univariate risk aversion and insurance demand for losses that affect many aspects of well-being. In that case, we can estimate an empirical model where the dependent variable is insurance demand, and one of the independent variables is the level of the risk attitude of interest. Furthermore, our findings can be tested by examining the direction of association between the level of one aspect of well-being and insurance demand. One example of a bivariate risk is the case of supplemental disability insurance.

Our framework can be utilized for preferences beyond the setting of household finance. Mossin’s theorem can be also considered from the insurer’s perspective (Chi et al. 2023). In the study of multidimensional risk, the properties of reward–risk ratios regarding decision making should be carefully considered. Cheridito and Kromer (2013) study reward–risk ratios regarding structural properties such as monotonic and quasi-concave. Quasi-concavity leads to preferences that value averages higher than extremes. Correlation-averse preferences are risk-averse by summarizing all of the attributes in one dimension (Lichtendahl et al. 2012) and indicate preferences to diversification. How risk-return profiles and performance measures are presented to buyers can have a substantial impact on decision making and demand (Gatzert and Schmeiser 2013). In the next section, we explore how this proposition can be further utilized in the economic literature. We specifically consider the case of preferences on income and health.

4. Discussion

The above proposition has some implications for disability insurance. A disability event would impact both the health status and income of households. We consider the two attributes above to be income \(x\) and health \(y\). For short- or long-term disability insurance, a loss in health status will cause a loss in the income. Also, our earlier assumption \((a < 1)\) is reasonable because full or over insurance is not available. Over recent years, disability benefits have become less generous in many countries (Bernasconi et al. 2024). The average payment from public insurance in 2023 has been estimated to be about USD 1,358 in the United States (Carroll et al. 2023). The private disability insurance market complements the public Social Security Disability Insurance system by providing additional coverage (Autor et al. 2019). In the disability insurance case, incompleteness can be considered in the sense that nonpecuniary loss (health) cannot always be covered.

A paper by Scott and Finke (2013) reports on the demand for private disability insurance by using variables that are related to financial characteristics, attitude, and demographics from the Survey of Consumer Finances. The Survey of Consumer Finances does not distinguish between short- and long-term disability. Scott and Finke (2013) create an empirical model for all households and then one for only employed households. The results are similar for both. They find evidence that the demand for disability insurance increases as the health level increases. Consequently, based on our proposition above, we conclude that preferences should exhibit IACA in order to be consistent with Scott and Finke’s (2013) empirical findings. Some studies propose a multiplicative separable utility function, \(U(x, y) = v(x) \cdot w(y)\), while others propose a utility function that is additive separable, \(U(x, y) = v(x) + w(y)\) (Picard 2016; Rey and Rochet 2004). However, the previous assumption of an additive separable utility function, as we have shown above, does not conform to the empirical evidence of Scott and Finke (2013). This form of utility function exhibits CACA. The multiplicative separable utility functions exhibit correlation-seeking when \(v(x)\) and \(w(y)\) are utility functions of \(x\) and \(y\), respectively (Rey and Rochet 2004).
However, this form of utility function can also exhibit correlation aversion when \( v(x) \) and \( w(y) \) are just expressions of \( x \) and \( y \) respectively (Eeckhoudt et al. 2007).

The literature on the utility function of health and income has focused on the sign of the cross-partial derivative, and the findings thus far have been inconclusive regarding whether decision-makers are correlation-averse or -seeking (Finkelstein et al. 2009; Macé 2015). However, our work, without focusing on the sign of the cross-partial derivative, provides support to the idea that the properties of the absolute correlation aversion index, \( C(x, y) \), as presented in Definition 1, for the first time in the literature, play an important role. The existing literature shows only how similar properties of the absolute risk-aversion coefficient for bivariate utility functions are useful in the study of insurance demand, such as the results discussed in the paper of Malevergne and Rey (2009). Our argument, in the context of private disability insurance, in support of preferences that exhibit IACA, is consistent with the utility functions on income and health, suggested by empirical studies in various contexts, for instance, Levy and Nir (2012).

5. Conclusions

Our study provides a classification of bivariate utility functions based on the index of absolute correlation aversion. We revisit Mossin’s theorem in an insurance setting where one common source of risk impacts two aspects of individual well-being, and we derive testable implications about this classification of utility functions. Specifically, we apply our bivariate insurance setting to preferences on income and health in the context of disability insurance. Although disability risk has high consequences for households’ well-being, this type of labor income insurance has not received the same attention in the literature as other types of insurance. Using evidence from the Survey of Consumer Finances literature on the demand for private disability insurance, we show that multiplicative separable preferences on income and health appear to better fit observed behavior. We finally provide an argument that the utility function’s properties with respect to the index, such as the increasing absolute correlation aversion property, are more important than whether decision makers are correlation-averse or correlation-seeking in the study of insurance demand.

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Notes

1 Subscripts 1 and 2 in the utility function indicates the derivative with respect to \( x \) and \( y \), respectively, i.e., \( U_{x12}(x, y) = \frac{\partial^2 U(x, y)}{\partial x \partial y} \) and \( U_{111}(x, y) = \frac{\partial^4 U(x, y)}{\partial x^3} \).

2 The correlation coefficient is 1 for lottery B and \(-1\) for lottery A.

3 The classification in Definition 1 covers all the specifications of preferences in wealth and health used in the literature (Rey and Rochet 2004).

4 Eeckhoudt et al. (2007) actually use the terms cross-prudent in health and cross-prudent in wealth when \( U_{112}(x, y) \geq 0 \), and \( U_{122}(x, y) \geq 0 \) respectively. We have not yet imposed any assumption of what aspect of wellbeing each variable represents.

5 In that case, the probability density function \( f_{x-y}(\tilde{x}, \tilde{y}) \) can be expressed as \( f_{x-y}(\tilde{x}) \).

6 The literature examines basic principles of insurance demand in various frameworks that are different from ours in many aspects, such as Rey (2003). Also, full insurance with a fair premium is not surprising as a constrained optimum, when considering the specification of perfect monetary health equivalent described in Rey and Rochet (2004), but not for correlation-seeking utility functions.

7 Alternatively, by utilizing the implicit theorem, the conclusion is the same since near \( (x^*, Y) \), \( \frac{\partial y^*}{\partial x} = -\frac{\frac{\partial U_1(x, y)}{\partial x}}{\frac{\partial U_2(x, y)}{\partial y}} < 0 \).


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