

# **The Nature of Risk**

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Language can sometimes be confusing. In English, there are more concepts than there are words, so many words have multiple meanings. Words that have one meaning in everyday usage may have an entirely different meaning in a specific context. When one speaker is using the everyday definition and another is using the a specific contextual definition, confusion can occur.

One word that is particularly susceptible to misunderstanding is the word “risk”. The concept of risk is important in many areas of finance, yet there seems to be no consensus concerning the definition of the term. Textbook authors all define risk in their own different way, and these definitions are not the same. It is necessary to establish a clear definition for the concept of risk that is consistent with established risk measurement methods.

## **What Risk Is Not**

Risk is often associated with loss or the probability of loss. While this may be an association used in everyday speech, it is neither complete enough or accurate enough for formal use in finance. Consider the following two situations:

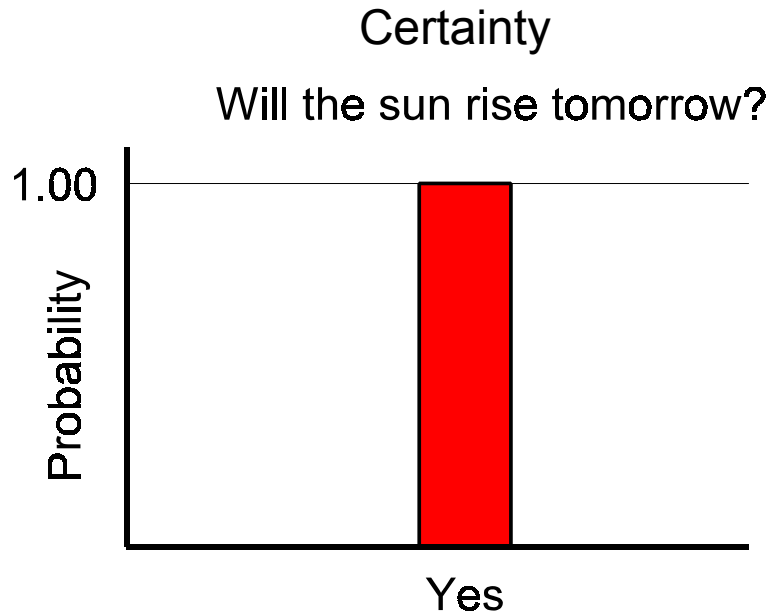
No-Risk Loss: You give me \$100. I will put the money in my pocket, and you receive nothing in return. In this case, you are certain that you will lose your money. There is no risk, and you will lose \$100.

No-Loss Risk: You invest \$100 in a project that will pay you either \$110 or \$150 at the end of one year. In this case, you will not have a loss, though you do not know how much you will gain, so you may be at risk.

While risk may be associated with loss, loss is not necessarily associated with risk. This is one of those cases where common usage is technically incorrect. Risk is a more subtle concept than loss or the probability of loss. Since risk is one of the really important concepts in finance, it is necessary to have a really good definition.

## The Definition of Risk

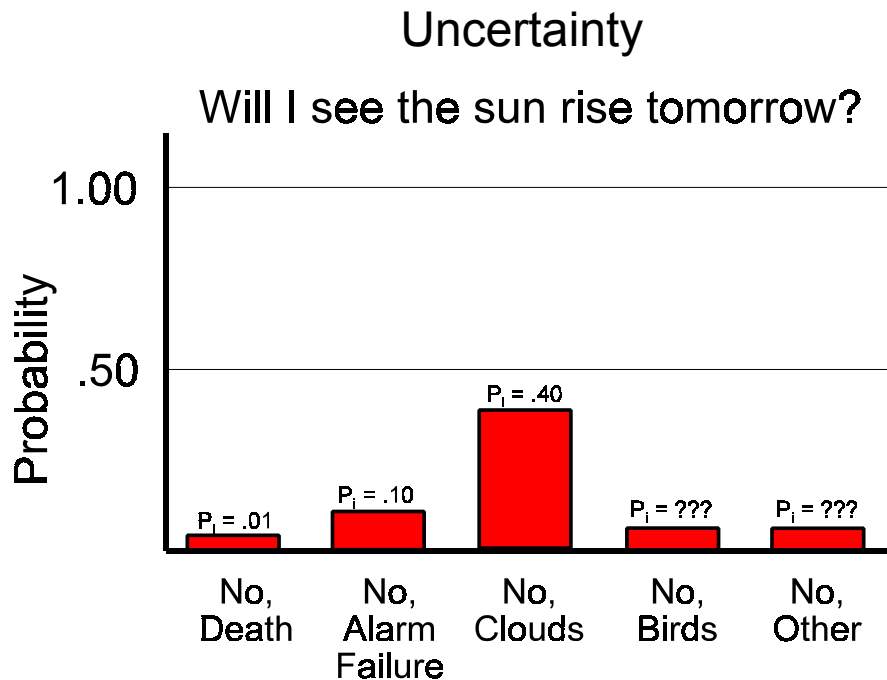
The concept of risk is not restricted to finance or financial investments. Virtually any question can be phrased to place it in the context of risk and risk analysis. Consider the question “Will the sun rise tomorrow morning?” The distribution of possible answers associated with that question is shown below.



The sun will rise tomorrow. (While a purist might try to argue for the possibility of a supernova or the destruction of the solar system through a cataclysmic event, such occurrences would render the entire argument moot.) This is an example of certainty. There is only one possible outcome, and that outcome occurs 100% of the time. Certainty is rather boring, and it takes no managerial or financial talent to handle this type of situation. You will not be paid for managing a certainty since there is nothing to manage.

A more interesting question is “Will I see the sun rise tomorrow?” While each of us hopes to see the next sunrise, many things could happen to prevent this from happening. A person could die in his sleep; actuarial tables provide some insight concerning the probability of this outcome. The alarm clock, either electrical or mechanical, could fail, and probabilities of power system or mechanical failures could be estimated. The sky could be overcast, but meteorological data could be used to determine the probability of this occurrence.

But there is no way to list or calculate the probabilities of all possible occurrences. It could be that a person lives through the night, wakes up to the alarm, looks out the window into a clear morning sky, and just as the sun begins to rise, the view is obstructed by a flight of migratory birds that just happen to be in the wrong place at the right time. Though this might be an extremely unlikely outcome, it could happen and prevent a person from actually seeing the sun rise. The distribution of possible outcomes for this situation is shown below.



This is an example of uncertainty. Not all possible outcomes are known, or if they are known it is not possible to obtain a meaningful probability estimate for each possible outcome. This is the type of situation most often faced in real life. Not everything is known due to various constraints, and a decision is most often made with imperfect knowledge. Unfortunately, there are no really good decision rules for working under uncertainty.

Decisions under certainty are not necessary, and decisions under uncertainty are difficult to model. In order to develop techniques that permit the use of quantitative information in decision making, uncertainty must be transformed into risk. The situation that is uncertain is reviewed to identify outcomes that, while possible, are unlikely. Once these unlikely outcomes have been eliminated from consideration, the remaining outcomes can be assigned probabilities reflecting their relative occurrence. The rejection of unlikely

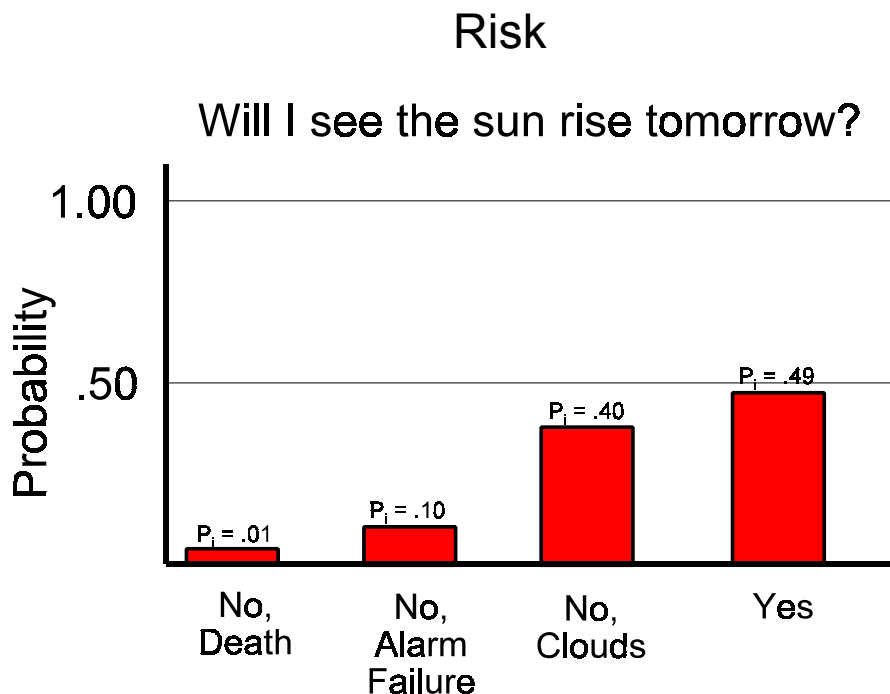
outcomes leads to the possibility that an unexpected outcome might occur, but this is consistent with making decisions with a confidence level, say 95%. In rejecting 5% of the possible outcomes as unlikely, it is possible to make a decision and get on with business, though there is a 1 in 20 chance that an unexpected “surprise” will occur.

Risk is a state of nature somewhere between certainty and uncertainty, and the formal definition is that risk is:

**Risk is the state of nature in which:**

- 1) there are multiple possible outcomes, and**
- 2) all possible outcomes are known, and**
- 3) the probability of each outcome is known, and**
- 4) the sum of the probabilities of the possible outcomes is 1.00.**

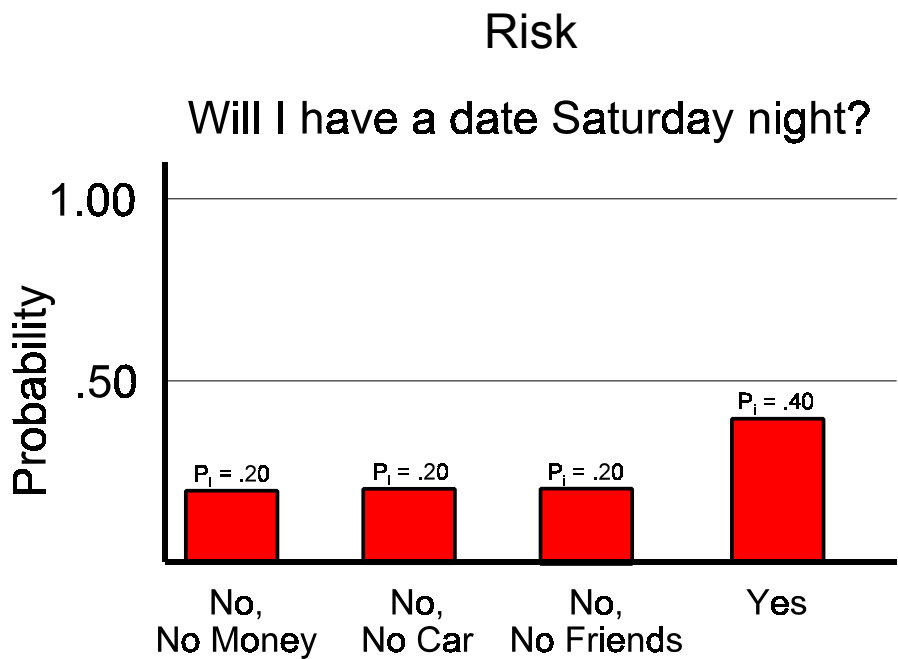
For the question “Will I see the sun rise tomorrow?”, if the probability that a flock of migrating birds is considered small enough to be ignored, it is eliminated as a possible outcome. Other rare occurrences can similarly be rejected as unlikely. A risk distribution for this question is shown below.



Outcomes that are considered highly unlikely are ignored, and the decision is made using the “best” set of information available. It could indeed happen that a flock of birds could obscure the sunrise, but that is why decisions in risk situations are made with specified confidence intervals. It is neither certainty nor uncertainty, it is risk.

Risk is that state of nature that lies between certainty and uncertainty. It might occur naturally, as with a situation that has only a specified number of outcomes, like a binary outcome such as a flipped coin land that can only land head or tails. It might be necessary to define away certain highly unlikely outcomes in order to simplify a complex problem. In any case, the structure of the situation defined as risk allows mathematical tools to be employed for decision making.

Note that this definition of risk is general and does not specifically relate to finance. Risk can exist any time the necessary conditions exist. Consider the question posed by many students, “Will I have a date Saturday night?” A distribution of possible outcomes to this question is shown below.



In three of the possible outcomes, there will be no date due to the lack of money, a car, or friends. But if one has money, a car, and friends, then a Saturday night date will

occur. This illustrates that risk is all around in everyday life, not just finance. Risk is not specific to a field of study, it is a fundamental aspect of life.

It is important to realize that risk is not some ambiguous concept. It is the manner in which we describe the world around us so that we can make decisions. If you know what the outcome will be before the event (will the sun rise?), there is no need to make a decision. If you do not know the outcome and you must make a decision, you must first determine the relevant possible outcomes and convert uncertainty to risk. Once a question is phrased in the context of risk, quantitative methods can be used to help in making the decision.

### **Measuring Financial Risk**

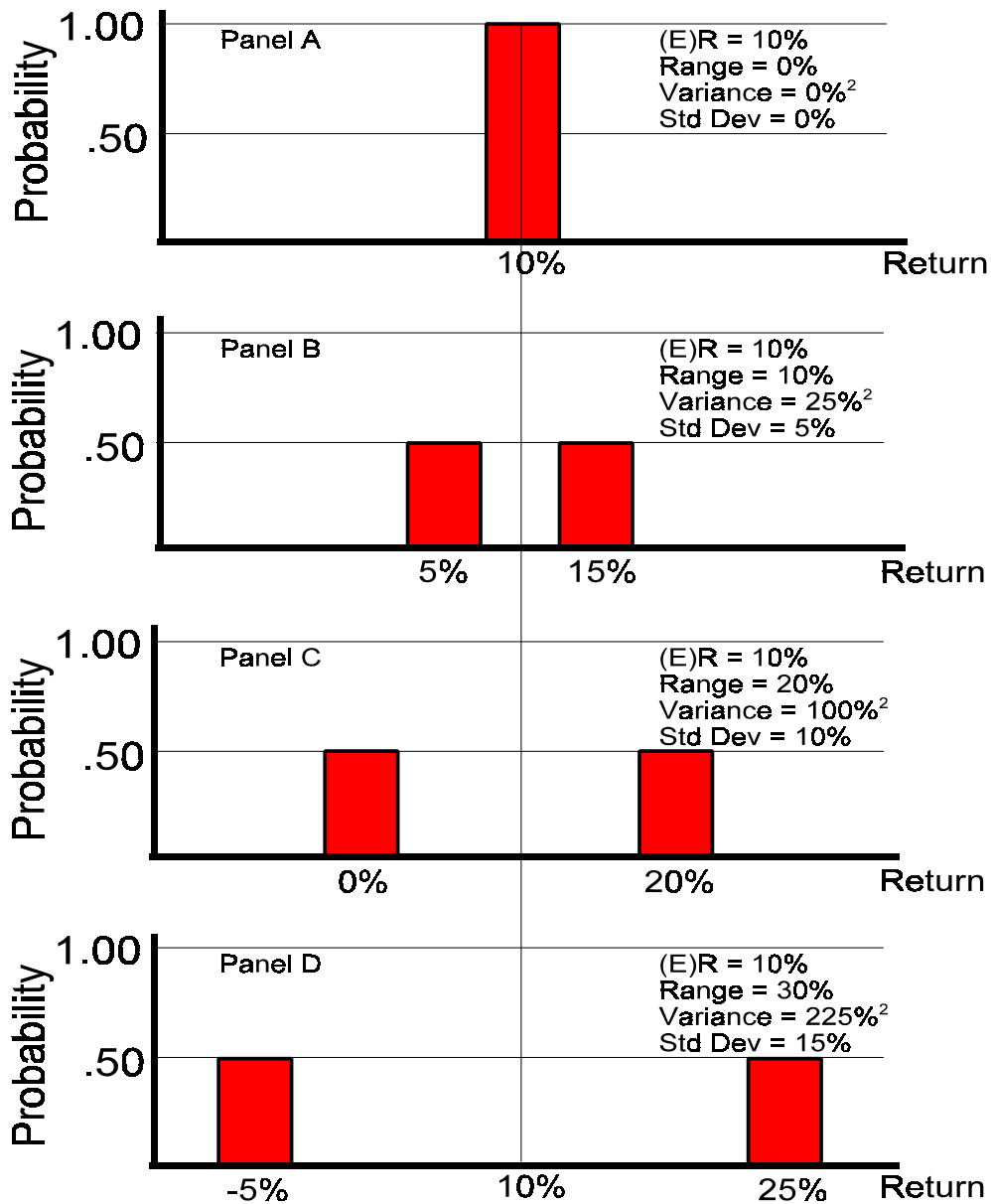
Risk must be defined within a specific context. In finance, investments are evaluated on the basis of the returns they offer where return is calculated as:

$$\text{Return} = \frac{\text{Amount Received}}{\text{Amount Invested}}$$

Return is a relative concept that allows investments of different magnitudes to be compared. Risk in finance is defined on a set of returns. It is important to note that risk is defined on returns, not the other way around. It should also be noted that since risk is defined in the context of returns that risk cannot be spoken of without explicitly considering returns. While returns can be considered absent risk, the converse is not true.

There is still the question, though, of what makes different investments have different levels of risk. The following graph shows the risk profiles for four different investments. Panel A reflects a certainty since there is only one possible outcome. Panels B through D are all risk situations since there are multiple possible outcomes, all outcomes are known, the probability of each outcome is known, and the sum of the probabilities is equal to 1.00. It is instructive to note that only in Panel D is there a probability of loss. Panels B and C again illustrate that loss is not required for risk.

# Risk Measurement



In this example, the mean of each distribution of returns is 10%. Panel A shows a distribution of returns that is  $10\% \pm 0\%$ . The distribution of returns in panel B is  $10\% \pm 5\%$ . Panels C and D have distributions of returns of  $10\% \pm 10\%$  and  $10\% \pm 15\%$ , respectively. When asked which of the distributions contains the most “risk”, people almost always answer Panel D. Panel A has the least risk (no risk since it is a certainty), and the amount

of risk increases in Panels B through D. Risk apparently has something to do with the lack of certainty concerning the possible outcomes and the degree by which these outcomes differ from certainty. The wider the distribution and the further the possible outcomes are from certainty, the more risk.

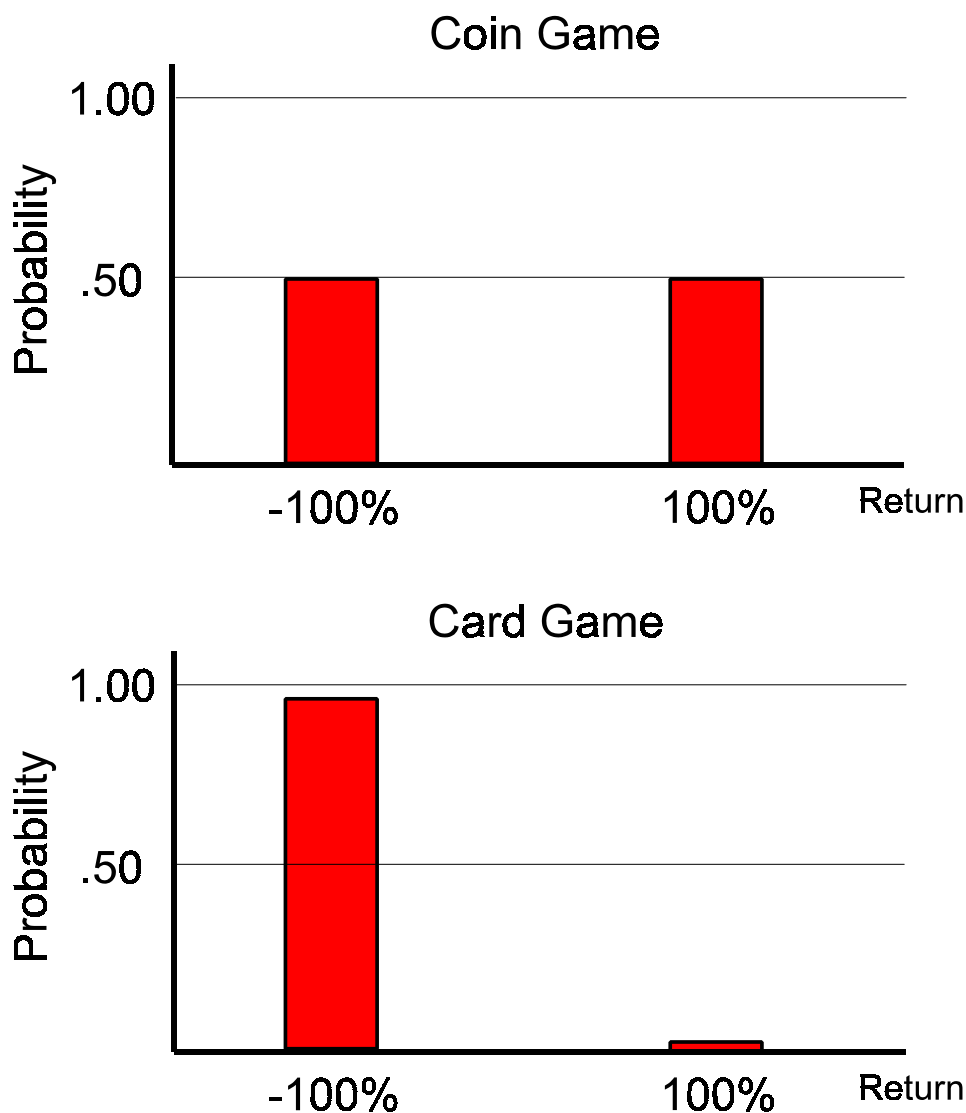
Risk is related to the width of the distribution of returns. Since the returns are themselves numeric, the problem of measurement of risk is simplified. The numeric techniques for measuring the width of a distribution have been developed for statistical analysis. The simplest measure of the width of a distribution is range, but for risk analysis this measure is inappropriate. The following two games illustrate the problem.

Coin Game: You put \$1 on the table, and I put \$1 on the table. I will flip a fair coin. If the coin comes up heads the money is yours; if it comes up tails the money is mine. In this game there is a 50/50 chance that either player will lose his \$1 (a 100% loss) or take the other player's \$1 (a 100% gain).

Card Game: You put \$1 on the table, and I put \$1 on the table. I will take two standard decks of playing cards, and from one deck I will remove all the aces. I now have a pack of 100 cards, and there are two of each value except the aces. I will shuffle all the cards together and allow you to pick one card. If that card is the ace of diamonds, the money is yours. If the card is anything else, the money is mine. In this game, 99 times out of 100 the player holding the cards wins, but the maximum loss is still 100%, and the maximum gain is still 100%.

This illustrates that risk is not the probability of loss nor the absolute width of the distribution of returns. In the card game, whoever holds the cards will win the vast majority of the time. The game does not change if a different player holds the cards. The risk in the game is constant, but the probability of an individual winning or losing depends on whether or not he is holding the cards. Risk is inherent to the game, not the position of the players. Loss is associated with the position of the players, not the risk of the game.

The range of the distributions in both games is identical as shown below, but the risk in the games is different. The outcome of the card game is almost certainly known before the game begins. The outcome of the coin game is unknown until the coin lands. Even if the coin game were modified so that the loser would give the winner fifty cents, the smaller range of the distribution would still contain more risk than the range of the card game since risk is related to lack of certainty and not the probability of loss.



Variance provides a useful measure of the width of a distribution, but since variance has inconvenient units,  $\%^2$ , its square root is defined as the standard deviation and used as a measurement of width. In Panels A through D, the standard deviations of the

distributions are 0%, 5%, 10%, and 15%, respectively. Those distributions with the greater risk have larger standard deviation values. Panel A, the certainty, has no risk, and the standard deviation of that distribution is 0%. Standard deviation thus can be used as a proxy to measure risk since it increases as risk increases.

These examples have shown that risk can be measured for stand alone assets, and comparisons can be made of the relative risk of different assets. There are other ways in which the risk and return of assets can be compared, for example, the coefficient of variation. When assets are put into a portfolio, the differing patterns of returns of the components require that measures of portfolio risk consider the interactions (correlations) of the portfolio components, and the systematic risk, which is only a portion of the total risk, is the relevant measure of risk in comparison with return. In all cases, though, calculations of risk are based upon the fundamental concept of return.

### **Risk Factors and Risk Creation**

One salient point in the discussion of risk deals with identifying risk factors. Risk is defined upon the distribution of returns of an asset. Therefore, only those factors that affect the distribution of returns can be considered risk factors. Whether the sun is shining or the day is overcast would not be a risk factor for a manufacturing company situated inside a building. But the sun's presence could indeed affect growing crops and the industries that process those crops. Sunshine is important in many aspects of the tourist industry, too. The question "Will the sun rise tomorrow?" is a certainty, but the question "Will the sun shine tomorrow?" may or may not indicate a risk factor.

If the factor causes the distribution of returns to shift, it is a risk factor. If the factor does not affect the distribution of returns, it is not a risk factor. Understanding this relationship between return and risk allows an analyst to identify those factors which are truly risk factors. Actions can then be taken to eliminate or minimize the risk that really does exist, and no effort needs to be wasted on factors which might only seem to cause risk.

## **Summary**

The concept of risk is important in the area of finance. While everyone has some idea of the meaning of "risk", there is a lot of confusion in defining the term. Risk is simple, yet subtle. Risk may involve loss, but it may not. Risk is not uncertainty, but it is related to the lack of certainty. Risk is based on returns, not vice versa, and any time the concept of risk is invoked, the concept of return must be present.

The meaning of risk in finance is not an arbitrary one. Risk is a very specific state of nature under which certain conditions obtain. Casual use of such a specific word can cause confusion. Understanding the formal nature of risk permits better analytical techniques and better management.