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Modeling Risk Aversion in Economics

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Economists have a shared preconception that, for the most part, people dislike risk. We typically assume that a person who is offered a choice between a risky lottery versus a sure payment equal to the expected value of that lottery will choose the latter. Similarly, when a person compares two lotteries with equal expected values, we assume that the person will choose the lottery with less risk. When an individual compares two lotteries where one has a higher expected value but also more risk, we assume that the person's choice will depend on the extent of risk aversion—for example, if risk aversion is small enough, the person will choose the lottery with higher expected value and more risk.

This risk-aversion intuition is a key driver in many prominent economic applications. Risk aversion creates a demand for insurance, which gives rise to a large economics literature on health insurance, unemployment insurance, property insurance, flood insurance, and so forth. Risk aversion plays a central role in financial investment, driving the key trade-off between risk and return in the pricing of financial assets. Risk aversion is relevant in principal–agent models, and is the source of the incentives–insurance trade-off that commonly arises in such models. Risk aversion is also important in life-cycle models as people face risk concerning employment, income, asset returns, health, and so forth.

To capture the risk-aversion intuition, the standard approach in economics has been to utilize the model of expected utility, in which risk aversion derives from

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diminishing marginal utility for wealth (or diminishing marginal utility for aggregate consumption). The expected utility model is extremely tractable and portable into a wide variety of applications and has been used to derive many important insights. Moreover, expected utility permits a measure of the degree of risk aversion, and thus makes it possible to obtain quantitative estimates of risk aversion, or to develop (and estimate) models with heterogeneity in the degree of risk aversion.

But over the years, economists and psychologists have identified various issues with expected utility as a descriptive model of choice. In this journal, Rabin and Thaler (2001) highlight how the structure of expected utility generates a calibration problem in dealing with stakes of different sizes, and as a result expected utility does not permit seemingly plausible preferences—for example, it does not permit people to exhibit noticeable but modest risk aversion for both small and moderate stakes. Perhaps more importantly, researchers have pointed out predictions of expected utility that do not seem to accord with empirical observation, and over the past two decades a number of economists have pursued alternative ways to model risk aversion.

Our goal in this article is to urge economists to take seriously the research agenda of developing and assessing different ways to model risk aversion. We proceed in three main steps. First, whereas many economists seem to take expected utility with diminishing marginal utility for wealth to be synonymous with risk aversion, we highlight that the basic intuition of risk aversion that drives many results in economics is not intimately tied to expected utility. Second, we describe a few alternative models that can also capture the basic intuition of risk aversion. Finally, we discuss that, while expected utility and the alternative models might all capture the basic intuition of risk aversion, the alternative models can generate additional, more nuanced implications not shared with expected utility, that in some cases seem to be borne out by data. As we will highlight, these alternative models also are not perfect, and further research is needed to identify even better approaches.

Expected Utility and Risk Aversion

An option that involves risk can be described by a lottery, which is a list of possible outcomes along with the probability associated with each outcome. A choice between risky options can thus be thought of as a choice between lotteries, and to model how people make such choices, we need a model of how people evaluate and compare lotteries. Expected utility is exactly such a model.

According to expected utility, a person has a utility function that assigns a "utility" to each outcome. The overall evaluation of a lottery is then a weighted average of the utility from each possible outcome, where the weight attached to each utility is simply the probability of that outcome occurring. In other words, the person is assumed to choose the option that yields the largest expectation of utility.

The concept of *risk aversion* is typically applied when a person is choosing between lotteries where the outcomes are expressed in monetary amounts. For

instance, a person might face a choice whether to accept or reject a 50:50 gamble to lose \$10 or win \$10. A common definition of risk aversion is that, for any lottery, a person prefers a sure payment equal to the expected value of the lottery to facing the lottery itself. Under this definition, because a 50:50 gamble to lose \$10 or win \$10 has an expected value of \$0, a risk-averse person would reject this lottery.

Expected utility yields a simple and elegant explanation for risk aversion: under expected utility, a person is risk-averse—as defined in the prior paragraph—if and only if the utility function over monetary wealth is concave. In other words, risk aversion derives from diminishing marginal utility for monetary wealth. Expected utility therefore attributes the decision to reject the 50:50 gamble to lose \$10 or win \$10 to the idea that the utility decline from having one's wealth be \$10 smaller is larger than the utility increase from having one's wealth be \$10 larger.

Expected utility becomes especially useful when, unlike in the example above, a person is choosing between lotteries with different expected values. For instance, now consider a 50:50 gamble to lose \$10 or win \$12, which has an expected value of \$1. The decision whether to accept or reject this lottery involves a trade-off: accepting the gamble means taking on risk, but it also means a higher expected value. Expected utility yields a way to resolve this trade-off. Specifically, it permits a measure of the degree of risk aversion such that the person will accept the gamble if risk aversion is small enough, and otherwise the person will reject the gamble.[1]

In applications, economists often use a specific functional form for the utility function over wealth. One prominent functional form is the constant relative risk aversion utility function, in which there is a single parameter, ρ, that captures the degree of a person's risk aversion.[2] In the example above, a person with prior wealth \$50,000 would accept the 50:50 gamble to lose \$10 or win \$12 as long as ρ is smaller than 831. To help illustrate ideas, we often describe the implications of the constant relative risk aversion utility function in the examples below.

More generally, the existence of a measure of a person's risk aversion makes the model quite powerful. It permits analyses that use data on observed choices to estimate an individual's risk aversion or the distribution of risk aversion in a population. Perhaps more importantly, it also makes the model quite portable in that, once one has estimated a person's degree of risk aversion in one domain—for example, with the constant relative risk aversion utility function and an estimate of a person's ρ—the model makes predictions for how that person would behave in other domains.

To further highlight the basic intuition of risk aversion, and how it is not intimately tied to the expected utility model, we next describe how this intuition operates in three classic textbook domains: insurance, financial assets, and agency.

[1] Two common measures are the coefficient of absolute risk aversion and the coefficient of relative risk aversion, both defined by Pratt (1964) and Arrow (1965).

[2] The functional form is $u(x) = x^{1-\rho}/(1-\rho)$ for $\rho \neq 1$ and $u(x) = \ln x$ for $\rho = 1$.

Insurance

Suppose an individual is exposed to a potential loss of $10,000 that has a 5 percent chance of occurring, but also has the option to purchase full insurance—that is, an insurance policy that pays out $10,000 in the event that the loss occurs—for a premium of $600. This person is choosing between two lotteries. If the person does not buy insurance, then this person faces a lottery in which there is a 5 percent chance that wealth will decline by $10,000, and a 95 percent chance that wealth is unaffected—and thus, in expectation, wealth will decline by $500. If the person purchases insurance, then wealth declines by $600 with certainty.

In this domain, the intuition of risk aversion implies that a person who dislikes risk should be willing to give up some expected value in order to reduce risk and thus the willingness to pay for insurance should be larger than the actuarially fair price. In the example above, the intuition of risk aversion implies the person should be willing to pay more than $500 for full insurance. Moreover, a person who is more averse to risk will be willing to pay more for insurance. Whether this individual is willing to pay the premium of $600 will depend on whether the individual is sufficiently risk-averse.

Extending this example, suppose the person can choose how much insurance to purchase where insurance is priced linearly at a rate of 6 cents per dollar of insurance. In other words, this person can insure against the full loss for $600, insure against half the loss for $300, insure against a quarter of the loss for $150, and so forth. The individual now faces a choice not just between two lotteries, but rather between an array of lotteries with different coverage levels. This decision involves a trade-off: purchasing more insurance reduces risk, but it also reduces expected value. The intuition of risk aversion does not say where a person should end up, but it does suggest that an individual who is more risk-averse should choose a higher coverage level.

The basic conclusions above follow from the simple intuition of risk aversion, and, importantly, they do not require the expected utility model. The value of applying expected utility is that it can yield more quantitative statements—for example, with the constant relative risk aversion utility function, a person with $\rho = 5$ and prior wealth $50,000 would choose to cover $8,126 of the potential $10,000 loss. More importantly, expected utility permits analysis of many more nuanced questions, such as the nature of optimal risk sharing, the role of deductibles or coinsurance in combating moral hazard, and so forth. It also permits structural empirical analyses—for instance, in the context of auto insurance, Cohen and Einav (2007) apply expected utility to study heterogeneity in risk aversion and the implications of this heterogeneity for insurance pricing.

Financial Investment

Suppose an individual must decide how to divide personal wealth between two assets, a risk-free asset (like bonds) and a risky asset (like stocks). The risk-free asset has price normalized to $1 and pays out $1 per share (a return of zero). The risky asset also has price of $1, but its payout is uncertain: there is a 90 percent chance that it pays out $1.05 per share, and there is a 10 percent chance that it pays out

$0.90 per share. Hence, the risky asset involves a larger expected return than the risk-free asset (3.5 versus 0 percent), but also carries the possibility of doing worse.

In deciding how to divide personal wealth, the individual faces a trade-off: investing more in the risky asset yields a higher expected final wealth (or, equivalently, a higher expected return), but it also creates more risk. While the intuition of risk aversion does not say where any given person should end up, it does suggest that the more risk-averse a person is, the less that person should invest in the risky asset.

Extending this example, now suppose the price of the risky asset is endogenous. In particular, suppose the risky asset has a fixed supply of shares and the payout per share is as above. However, the price adjusts such that the demand for those shares is equal to the supply of those shares. This demand might come from a homogeneous population in which everyone invests the same amount in the risky asset, or it might come from a heterogeneous population in which people invest different amounts in the risky asset. The intuition of risk aversion implies that individuals will hold the risky asset only if it generates a higher expected value than the risk-free asset, and therefore implies that risky assets should pay a higher expected return than risk-free assets. Moreover, the risk-aversion intuition implies that if the population becomes more risk-averse, the expected return on the risky asset must increase (or, equivalently, the price of the risky asset must decline).

As for the basic conclusions in the insurance domain, the basic conclusions above follow from the simple intuition of risk aversion, and they do not require the expected utility model. Again, expected utility can yield more quantitative statements. For example, with the constant relative risk aversion utility function, a person with $\rho = 20$ and prior wealth $50,000 who faces an exogenous price of $1 per share of the risky asset will invest $24,746 in the risky asset. If prices were endogenous and there were a homogeneous population with $\rho = 20$ and 20,000 shares of the risky asset per person, then the equilibrium price for the risky asset would be $1.009 per share, yielding an expected return of 2.6 percent. If this population became more risk-averse in the sense that everyone had $\rho = 40$, then the demand for the risky asset would decrease leading to a new equilibrium price of $0.968 per share, yielding an expected return of 7.0 percent.

However, the real value of applying expected utility to study financial investment is that it permits much more complex analyses. As a classic example, the consumption capital asset pricing model builds from expected utility—in particular, from diminishing marginal utility from aggregate consumption. The model implies that assets whose returns are positively correlated with aggregate consumption will be less valued than assets whose returns are negatively correlated with aggregate consumption, and that the strength of this effect depends on the degree of risk aversion (for an overview of the consumption capital asset pricing model, see Breeden, Litzenberger, and Jia 2015).

Principal–Agent Relationships

Consider a principal–agent paradigm in which a risk-neutral principal hires a risk-averse agent to complete a task. This framework can be used to describe a

number of interesting economic situations, such as the relationship between a real estate agent and a buyer, an elected official and a group of voters, a firm and an employee, or the managers of a company and its stockholders.

As a concrete example, consider a tenant–farmer (the agent) who might enter into a contract with a landlord (the principal). The tenant exerts effort that affects the farm's crop yield, although the crop yield also depends on other random forces, such as the weather and the appearance of pests. The landlord benefits from selling the crops, and then the landlord compensates the tenant. Because the landlord cannot observe the tenant's effort, and can only observe the realized crop yield, the landlord's compensation to the tenant can be conditional only on the observed crop yield. The tenant has the outside option of getting work as day laborer with a certain wage, and will only accept the contract offered by the landlord if it will make the tenant at least as well off.

To incentivize effort, the landlord must make the tenant's compensation depend on the realized crop yield—otherwise the tenant will exert no effort. However, because the crop yield depends on more than just effort, this form of contract imposes risk on the agent. The intuition of risk aversion implies that, when signing the contract, the agent will demand to be compensated for taking on this risk. As a result, the optimal contract from the principal's perspective yields smaller profits for the principal than would occur if the principal could observe and contract directly on effort. Intuitively, if the landlord could directly contract on effort, then he could demand the efficient level of effort while simultaneously imposing no risk on the tenant. In contrast, when the landlord can contract only based on crop yield, the landlord must provide extra compensation to the farmer for bearing risk.

Some form of this incentives–insurance trade-off is at the heart of many principal–agent analyses. Yet again, the basic conclusions above follow from the simple intuition of risk aversion, and, importantly, they do not require the expected utility model.

Decoupling Risk Aversion from Expected Utility

In each of the three domains above, we have emphasized how many of the basic conclusions often attributed to expected utility in fact follow in a straightforward way from the simple intuition of risk aversion. Expected utility has its value—beyond capturing the simple intuition of risk aversion—only when one moves towards more quantitative analyses or more complex, nuanced predictions.

As we shall soon see, however, other models can also capture the simple intuition of risk aversion, and thus would yield the same basic conclusions in the three domains above. However, when we move toward more quantitative analyses or more complex, nuanced predictions, these alternative models often yield different conclusions. Moreover, in many instances, these different conclusions seem more in line with the empirical facts than the conclusions derived from expected utility. Later in the paper, we revisit the three domains above in order to demonstrate these points. But before turning to alternative models, we highlight an important flaw in the expected utility model.

The Calibration Problem

Rabin (2000) and, in this journal, Rabin and Thaler (2001) point out a serious flaw with the expected utility model: the structure of the model rules out seemingly plausible preferences due to a calibration problem in dealing with stakes of different sizes—for example, the model can have problems simultaneously explaining choices over small stakes and choices over moderate stakes.

To illustrate the issue, consider the earlier example in which a person with a constant relative risk aversion utility function and prior wealth \$50,000 would accept the 50:50 gamble to lose \$10 or win \$12 only if ρ is smaller than 831. Suppose we observed such a person reject this bet, implying ρ is larger than 831. Any such ρ would imply the person would also reject a 50:50 gamble to lose \$100 or win a huge positive amount like \$1 trillion—in fact, the model implies that a person with this wealth and risk aversion would reject the 50:50 bet that risks a loss of \$100 no matter how large the potential positive gain.

This flaw does not rely on the functional form assumption for the utility function. Rabin (2000) proves a theorem that implies that, for any functional form, if a person rejects a 50:50 gamble to lose \$10 or win \$12 for a range of prior wealths, the expected utility model puts strong restrictions on how that person must behave for larger stakes. This calibration problem derives from the fact that, using the expected utility model, risk aversion is attributed to diminishing marginal utility over wealth. Hence, if one exhibits noticeable and significant risk aversion over small stakes, it implies significant local curvature of the utility function. If that noticeable risk aversion over small stakes applies over a range of prior wealth, it adds up to a huge amount of curvature over larger stakes.

Hence, the structure of the expected utility model puts serious constraints on individual preferences. For instance, expected utility—with no restrictions on the utility function—implies that a person could not have the following preferences over 50:50 gambles:

1) Reject a 50:50 gamble to lose \$10 or win \$12 for any prior wealth between \$49,000 and \$60,000.
2) Accept a 50:50 gamble to lose \$100 or win \$9,000 for prior wealth \$50,000.

Whether a person has such preferences ought to be an empirical question—and it surely seems plausible that some people might. Under expected utility, however, it is not an empirical question, because the model implies that this pattern of preferences simply is not permitted.

For some applications, the expected utility calibration problem might not be a major issue. Most notably, in applications that focus on a single choice for each individual, or that focus on multiple choices for each individual that all involve similar-sized stakes, the calibration problem may not be much of a problem. However, in applications where individuals make multiple choices over different-sized stakes, the calibration problem can be important. Moreover, the calibration

problem further implies that one must be extremely cautious when taking quantitative estimates of risk aversion derived from one environment and using those estimates to predict choices or conduct a quantitative welfare analysis in another environment.

We next turn our attention to some alternative models that can also capture the basic intuition of risk aversion and that also have advantages relative to expected utility. One advantage will be that these models do not suffer from the same calibration problem. But a more important advantage is that the alternatives sometimes better capture the empirical facts than expected utility, even in applications where the calibration problem is unlikely to be an issue.

Alternative Models of Risk Aversion

Alternative models of risk aversion, often motivated by the psychology and behavioral economics literature, are starting to provide new insights and empirical content to classic domains of risk. Much of our discussion will focus on two alternative models of risk aversion that were integral components in Kahenman and Tversky's (1979) prospect theory: loss aversion and probability weighting.[3] Loss aversion has been the most extensively applied alternative model of risk attitudes. The potential value of probability weighting has only recently been recognized by economists. We also briefly discuss a third alternative—context-dependence and salience—that is starting to gain some traction. As we'll see, these models maintain the basic structure of expected utility, but introduce alternative sources of risk aversion. While we discuss each model independently, the best approach to modeling risk preferences might incorporate multiple sources of risk aversion, perhaps including diminishing marginal utility of wealth.

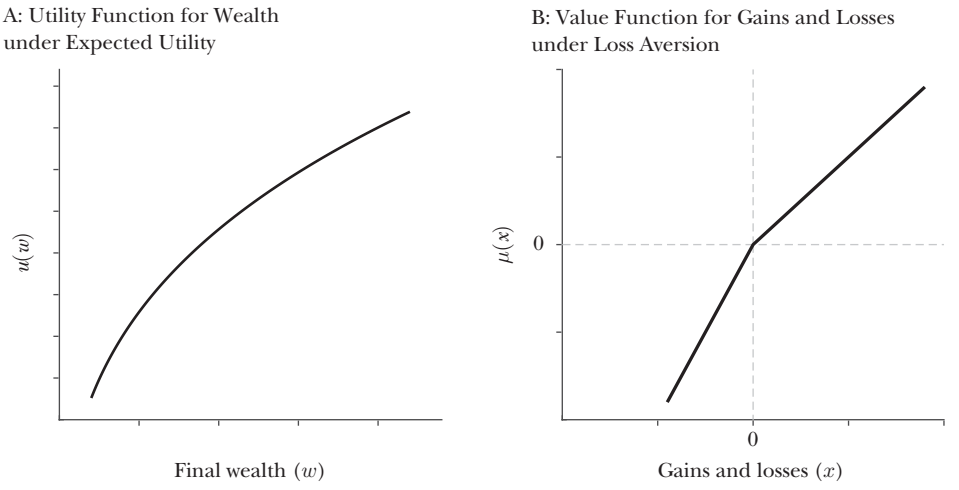
Loss Aversion

The model of loss aversion has much the same structure as expected utility, except that expected utility's utility function for wealth (depicted in Figure 1A) is replaced by a value function for gains and losses (depicted in Figure 1B).

The model of loss aversion involves two key features. First, instead of thinking in terms of final wealth, a person evaluates outcomes in terms of gains and losses relative to some reference point. To illustrate, consider a person with prior wealth $50,000 who has the option to accept or reject a 50:50 gamble to lose $10 or win $12. According to expected utility, the person compares having the utility of $50,000 with certainty versus a 50:50 chance having the utility of $49,990 or the utility of $50,012. Under loss aversion with a reference point equal to prior wealth, the person instead

[3] In this journal, Barberis (2013) provides a perspective on how Kahneman and Tversky's (1979) prospect theory had been used in economics over the three decades since it was written. Although we echo some themes of that article, we focus more explicitly on risk aversion.

Figure 1
Expected Utility versus Loss Aversion as a Basis for Risk Aversion



Source: Authors.
Note: The figure on the left depicts a utility function for wealth that might be used under expected utility. The figure on the right depicts a value function for gains and losses that might be used under loss aversion.

compares having the value of $0 with certainty versus a 50:50 chance of having the value of –$10 or the value of +$12.

The second key feature is that losses loom larger than gains: the negative value from a loss is larger (in magnitude) than the positive value from an equal-sized gain. Figure 1B depicts a simple, two-part-linear functional form for the value function that captures this feature. With this functional form, there is a single parameter, λ, that reflects the degree of loss aversion. Formally it indexes the relative slope in the loss domain versus the gain domain, so that $\lambda = 1$ implies no loss aversion and $\lambda > 1$ implies loss aversion, with larger λ implying more loss aversion. When a person evaluates options that involve both gains and losses, the "kink" in the value function between losses and gains will generate risk aversion.[4]

A major issue with loss aversion is the question of what determines the reference point around which gains and losses are defined. Kahneman and Tversky (1979) primarily assume that the reference point is prior wealth. However, applications of loss aversion have often posited different reference points. To illustrate the importance of what one assumes, consider a person with a two-part-linear value function who faces a choice between obtaining $10 with certainty versus a 50:50 chance to obtain $0 or $22.

[4] Kahneman and Tversky (1979) further assume that the value function exhibits diminishing sensitivity to the magnitude of gains and losses, which implies concavity in the domain of gains and convexity in the domain of losses. However, most applications of loss aversion in economics have adopted the two-part-linear functional form.

With a reference point of prior wealth, these two choices involve outcomes entirely in the domain of gains, and because the value function is linear in that domain, the person would be risk-neutral and thus choose the risky option. However, suppose instead that, when presented with this choice, the person starts focusing on the possibility of obtaining \$10 with certainty and uses this as the reference point. With this framing, the comparison becomes obtaining \$0 with certainty versus a 50:50 chance to lose \$10 or gain \$12. Now the kink becomes relevant, and if loss aversion is large enough (λ is large enough), the person would choose the certain gamble.

Of course, in the example above, both assumptions about the reference point are a bit arbitrary, making this an important degree of freedom in applications of the model. Motivated by this concern, Kőszegi and Rabin (2006, 2007, 2009) develop a model of loss aversion with endogenous reference points, wherein the reference point is determined by one's expectations about outcomes, and those expectations are determined by one's choice. Kőszegi and Rabin in fact posit several variants of how to think about endogenous expectations, depending on the nature of the situation.[5] Over the past decade, the literature has been heavily influenced by the Kőszegi–Rabin approach, and our discussion of loss aversion will primarily focus on the value of this approach.

Before we conclude this initial discussion of loss aversion, we highlight two further features. First, models of loss aversion need not suffer a calibration problem. As discussed above, under expected utility, if someone would reject a 50:50 gamble to lose \$10 or win \$12 for a range of prior wealths, it implies significant local curvature of the utility function (for example, that in Figure 1A) over a range of wealth. Under loss aversion, in contrast, the same preference might only imply significant curvature of the value function (for example, that in Figure 1B) over the domain from –\$10 to +\$12. For instance, this would be the case if the reference point were prior wealth, and it can also be the case under the Kőszegi–Rabin model of loss aversion with endogenous reference points.

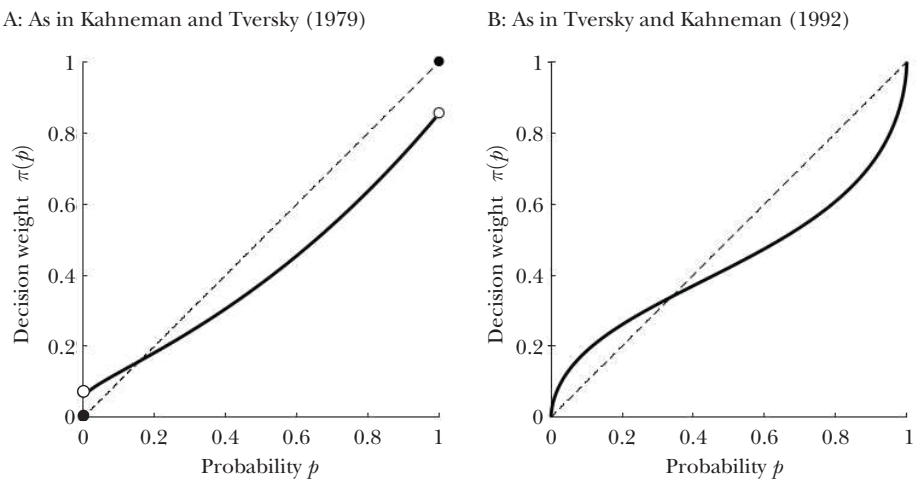
Second, note that the two-part-linear functional form in Figure 1B implies proportional risk preferences (under a reference point of prior wealth and under endogenous reference points). For example, if one rejects a 50:50 gamble to lose \$10 or win \$12 but accepts a 50:50 gamble to lose \$10 or win \$20, then one would reject a 50:50 gamble to lose \$100 or win \$120 but accept a 50:50 gamble to lose \$100 or win \$200. Models of loss aversion permit deviations from proportional risk preferences if the value function deviates from two-part linearity.

Probability Weighting

Under expected utility, the utility associated with each outcome is weighted by the probability of that outcome occurring. The basic idea of probability weighting

[5] See Kőszegi and Rabin (2007) for a description of two variants: "preferred personal equilibrium" and "choice-acclimating personal equilibrium." The latter shares some features with older models of "disappointment aversion" (Bell 1985; Loomes and Sugden 1986; Gul 1991). These distinctions will not be important for the discussion in this article.

Figure 2
Probability Weighting Functions as a Basis for Risk Aversion



Source: Authors.
Note: The figure on the left depicts the function that was suggested by Kahneman and Tversky (1979). The figure on the right depicts the one-parameter function that was proposed by Tversky and Kahneman (1992).

is that individuals might use decision weights that differ from the probabilities in systematic ways. To formalize this idea, one specifies a model for how probabilities are transformed into decision weights.[6]

Figure 2 illustrates two possibilities for a "probability weighting function" to use when making these transformations. Based on their original evidence, Kahneman and Tversky (1979) suggest a function similar to Figure 2A. Based on additional evidence, Tversky and Kahneman (1992) propose the function in Figure 2B, which also eliminates the discontinuity at the endpoints. Lattimore, Baker, and Witte (1992), Prelec (1998), and Gonzalez and Wu (1999) also suggest functional forms similar to that in Figure 2B. In each case, the horizontal axis shows the actual probability of an event, while the vertical axis shows the decision weight assigned to each probability. The 45-degree line thus corresponds to the decision weights under expected utility, and deviations from that line represent under- or overweighting of the objective probabilities.

Consider the implications of the probability weighting functions in Figure 2 for binary gambles. Specifically, consider a gamble with a probability p of getting \$10 and a probability $1 - p$ of getting a \$100. For gambles with small p (say, less than 0.2),

[6]Edwards (1954, p. 398) urged researchers to "think of a weighting function applied to the scale of objective probabilities which weights these objective probabilities according to their ability to control behavior."

the $10 receives a decision weight larger than its probability while the $100 receives a decision weight smaller than its probability. As a result, this gamble will look less attractive than it would to an expected utility maximizer—in other words, the probability weighting would generate a source of risk aversion. In contrast, for gambles with large p (say, greater than 0.8), exactly the opposite holds, and probability weighting would generate a source of risk seeking. Hence, unlike both diminishing marginal utility for wealth (as in expected utility) and loss aversion, probability weighting has somewhat more nuanced predictions, sometimes predicting risk aversion and sometimes predicting risk seeking.

While early formulations applied the probability weighting function to the probability of each outcome, this approach generates violations of dominance. Thus, it is now typical to use the rank-dependent approach proposed by Quiggin (1982) in which the probability weighting function is applied to the cumulative probability of each outcome. While this approach preserves the predictions above for binary gambles, it generates additional predictions for gambles with more than two outcomes. Specifically, rank-dependent probability weighting leads a person to overweight tail events and to underweight intermediate events.

Probability weighting has only started to be used more in economic applications, and issues remain to be worked out. For instance, the implications of probability weighting for 50:50 gambles is not entirely clear—and more to the point, different variants of probability weighting can predict risk aversion or risk seeking for such gambles. Perhaps more importantly, there is relatively limited discussion or consensus about the psychological principles that underlie probability weighting (for one discussion, see Burns, Chiu, and Wu 2010). However, as economists start to appreciate the potential value of probability weighting—as in the applications that we discuss below—we expect we will gain a deeper understanding.

Context-Dependence and Salience

The idea of context-dependence and salience is that the context or environment of a choice leads people to pay more attention to certain features of the choice situation. While this basic idea has a long tradition in psychology, it has proved elusive to formalize, especially in a way that can be used in economic applications. However, some promising models have been proposed in recent years, and this direction is worth additional exploration.

Context-dependence and salience can be thought of as providing a psychological mechanism for probability weighting. For example, in the salience model of Bordalo, Gennaioli, and Shleifer (2012), outcomes are weighted according to how much they differ from the average in a given state of the world, with more extreme payout states garnering more attention. When evaluating a lottery in which one has a 90 percent chance of winning $20 and a 10 percent chance of losing $100, there are two clearly defined states: the good state in which you win $20 if you take the bet versus nothing if you decline, and the bad state in which you lose $100 if you take the bet versus nothing if you decline. As the bad state involves more extreme outcomes, it attracts attention, resulting in the over-weighting of this low probability event.

The more general intuition is that in contexts where the downside of lotteries is salient, individuals will overweight those outcomes and exhibit risk aversion. Conversely, in contexts where the upside is salient, individuals may exhibit risk-seeking behavior. More importantly, context-dependence and salience can generate predictions that diverge from standard probability weighting, especially for gambles with more than two outcomes. In particular, because the context might include all options in a choice set, decision weights for one option might be influenced by other options in the choice set. As a result, unlike rank-dependent probability weighting where only extreme outcomes are overweighted, context-dependence and salience could lead to an overweighting of intermediate outcomes if attention is drawn there.

Of course, the big question—and a potentially big degree of freedom for researchers using this approach—is what determines salience. Several answers have been proposed. For example, Bordalo, Gennaioli, and Shleifer (2012) suggest that a feature will be more salient the more it differs from its average value in the choice set. Kőszegi and Szeidl (2013) suggest that a feature will be more salient if its range in the choice set is larger, while Bushong, Rabin, and Schwartzstein (2017) suggest that a feature will be more salient if its range in the choice set is smaller.[7] More work is needed in this area. Nevertheless, this approach has the potential to provide a more sophisticated and nuanced perspective, as we highlight in the next section.

Applications of Alternative Models

Having outlined three alternative models that can also generate risk aversion, we now revisit the three domains of insurance, financial investment, and principal–agent problems. For each domain, we describe the extent to which the alternative models do—and do not—capture the basic risk-aversion intuition for the simple behaviors discussed earlier. We then consider more nuanced behaviors to highlight how these alternative models can generate predictions different from expected utility that might accord better with empirical observations.

Reconsidering Insurance

Again, suppose an individual is exposed to a potential loss of $10,000 that has a 5 percent chance of occurring, with an option to purchase full insurance for a premium of $600. According to the simple intuition, a sufficiently risk-averse person might purchase this insurance.

[7] Bordalo, Gennaioli, and Shleifer (2012) explicitly explore the implications of their model of salience for risk preferences in the context of lotteries. Kőszegi and Szeidl (2013) and Bushong, Rabin, and Schwartstein (2017) do not explicitly discuss how their models apply to preferences over lotteries, though the intuition of range-based salience could also be applied in this domain.

In fact, loss aversion with a reference point equal to prior wealth does not generate risk aversion in this domain. With a reference point of prior wealth, all outcomes would (weakly) involve losses, and thus loss aversion—which is about comparing losses to gains—would become irrelevant.[8] However, loss aversion with an endogenous reference point (as in Kőszegi and Rabin 2006, 2007, 2009) nicely captures the intuition of risk aversion in this domain. When the reference point is endogenous, it might be determined by the choice to insure or by the choice not to insure. In either case, the comparison will involve gains and losses. Specifically, the outcome of –$10,000 will always be viewed as a loss relative to the outcomes of –$600 and $0, and the outcome of $0 will always be viewed as a gain relative to the outcomes of –$600 and –$10,000. Hence, the kink in the value function between gains and losses will generate risk aversion, and the person's willingness to pay for insurance will be larger than the actuarially fair price. Moreover, the larger is loss aversion (the larger is λ), the larger will be the willingness to pay, and thus the person would buy the full insurance if loss aversion is large enough.

Probability weighting can also generate risk aversion in this domain, but it need not do so. For our specific example, probability weighting with the most common functional forms—as in Figure 2—nicely captures the risk-aversion intuition. In particular, the 5 percent chance of the loss is overweighted, while the 95 percent chance of no loss is underweighted, which together will generate risk aversion and thus a willingness to pay for insurance that is larger than the actuarially fair price. Moreover, the stronger is this overweighting, the larger will be the willingness to pay.

But matters become more complicated with probability weighting as we consider insurance against events with different probabilities. Most notably, if the probability of a loss is relatively high—say, 80 percent—the probability weighting functions in Figure 2 imply that the loss event would be underweighted. In that case, probability weighting would predict risk-seeking behavior and a willingness to pay that is below the actuarially fair premium. For instance, if a person faced an 80 percent chance of a $1,000 loss, the person would not be willing to pay $800 for full insurance. While we do not know of empirical evidence on the demand for insurance as a function of the probability of a loss, we note that many of the salient forms of real-world insurance tend to be for smaller-probability events.

In principle, models of context-dependence and salience can also generate risk aversion in this domain. If the context makes the loss event salient, the resulting added attention would generate risk aversion and thus a willingness to pay for insurance that is larger than the actuarially fair price. In addition, factors that increase the salience of the loss event would increase the willingness to pay. Conversely, if instead the context makes the no-loss event salient, it would produce risk-seeking behavior. Because there is not yet a clear sense of what determines salience, more work is required to generate a clear prediction even for this simple example.

[8] If as in Figure 1B the value function is linear in the domain of losses, the person would be risk-neutral in insurance decisions. If instead there is diminishing sensitivity and the value function is convex in the domain of losses, the person would actually be risk seeking in insurance decisions.

Beyond being able to generate risk aversion in our basic insurance example, the alternative models have additional implications for more nuanced behaviors. For instance, researchers have found an applied version of the expected utility calibration problem in the insurance domain, and the alternative models can help to address it. Using micro-data on property insurance decisions, Sydnor (2010) finds that, when interpreted with expected utility, the amount that many customers pay to reduce their deductible from $1,000 to $500 implies extremely large and implausible levels of diminishing marginal utility for wealth. He then demonstrates how plausible levels of both loss aversion and probability weighting can be consistent with the level of risk aversion in his data.

For some behaviors, the alternative models make predictions about risk aversion that differ from the predictions of expected utility. For instance, suppose we expand our example above such that the insurance policy includes a deductible. How does one's willingness to pay for the insurance depend on the size of the deductible? The structure of expected utility implies that one's marginal willingness to pay to reduce a potential loss is larger the larger is that loss. For example, one's willingness to pay to reduce one's deductible from $750 to $500 is larger than one's willingness to pay to reduce one's deductible from $500 to $250, which in turn is larger than one's willingness to pay to reduce one's deductible from $250 to $0. In contrast, both loss aversion with an endogenous reference point and probability weighting imply that one's marginal willingness to pay to reduce a potential loss is independent of the size of the loss. Hence, one's willingness to pay to reduce one's deductible from $750 to $500 is the same as one's willingness to pay to reduce one's deductible from $500 to $250 and the same as one's willingness to pay to reduce one's deductible from $250 to $0.[9]

In fact, these different predictions for how the willingness to pay reacts to the magnitude of risk can be used in empirical work to distinguish risk aversion stemming from diminishing marginal utility for wealth from risk aversion stemming from these alternative sources. For instance, Barseghyan, Molinari, O'Donoghue, and Teitelbaum (2013) use data on household deductible choices for home and auto insurance to estimate a structural model of risk preferences that permits both diminishing marginal utility for wealth and "probability distortions," which they define to encompass both probability weighting and loss aversion. Taking advantage of the feature above, they estimate that the vast majority of risk aversion in their data is attributed to probability distortions.[10]

It is also instructive to return to our discussion of how much to insure given a linear price of 6 cents per dollar of insurance. Earlier, we highlighted how the simple intuition of risk aversion implies that a more risk-averse person should buy more insurance. The structure of expected utility additionally implies that, in fact,

[9]For simple binary (loss/no-loss) insurance, this pattern holds for preferred personal equilibrium, choice-acclimating personal equilibrium, and some variants of disappointment aversion.

[10]See Barseghyan, Molinari, O'Donoghue, and Teitelbaum (forthcoming) for a comprehensive discussion of estimating risk preferences in field settings.

the person should never fully insure no matter how large the individual's risk aversion is. This result follows from the fact that, in the expected utility model, starting from full insurance there is essentially no cost to taking on a small amount of risk. Hence, when insurance is actuarially unfair, it is always worthwhile to take on a little risk to get an increase in expected value. In contrast, under either loss aversion with an endogenous reference point or probability weighting, taking on a small amount of risk can be strictly costly, and thus it is possible to strictly prefer full insurance, even at an actuarially unfair rate.[11]

We have not discussed any specific predictions of context-dependent models here, because these models require further development. That said, we believe such models might eventually prove quite useful in the domain of insurance, especially for more complicated insurance products where the details of the insurance product could have a significant impact on what becomes salient and draws the attention of the decision maker.

Reconsidering Financial Investment

As before, suppose people must decide how to divide their wealth between two assets, a risk-free asset and a risky asset, where the risky asset involves a larger expected return than the risk-free asset but also carries the possibility of doing worse. According to the basic intuition of risk aversion, the more risk-averse a person is, the less that person should invest in the risky asset. Moreover, endogenous pricing of the risky asset implies that, with a risk-averse population, the price should adjust such that the risky asset has a larger expected return than the risk-free asset, and the more risk-averse is the population, the higher will be the equilibrium expected return on the risky asset.

Once again, loss aversion with an endogenous reference point nicely captures the intuition of risk aversion in this domain. Analogous to the insurance example, with the reference point determined by one's choice, the outcome when the risky asset pays a positive return will be viewed as a gain, while the outcome when the risky asset pays a negative return will be viewed as a loss. Hence, the kink in the value function between gains and losses will generate risk aversion, and the more loss-averse a person is (the larger is λ), the less likely the person becomes to invest in the risky asset. In addition, if the price of the risky asset is endogenous, loss aversion yields that the risky asset should have a larger expected return than the risk-free asset, and the more loss-averse is the population, the higher will be the expected return on the risky asset.

Under probability weighting, the implications for financial investment are more nuanced, depending on which states are underweighted and which are overweighted. For our specific example, the probability weighting functions in Figure 2 imply that the 90 percent chance that the risky asset yields a positive return should be underweighted, while the 10 percent chance that it yields a negative return

[11] This difference is related to first-order versus second-order risk aversion as discussed by Segal and Spivak (1990).

should be overweighted. The result is that the person would indeed display risk aversion, and thus probability weighting would nicely capture the intuition of risk aversion. More generally, though, probability weighting need not generate risk aversion—for example, if the risky asset had a small probability of a large positive return and a large probability of a small negative return.

Beyond being able to generate risk aversion in our basic financial-investment example, the alternative models have additional implications. This domain includes perhaps the most famous expected utility calibration problem: the equity-premium puzzle (Mehra and Prescott 1985), which is surveyed more recently in Mehra (2008) and in this journal by DeLong and Magin (2009). While diminishing marginal utility for wealth predicts that stocks should yield a greater return than bonds, the sheer magnitude of the differential that is observed empirically cannot be rationalized with reasonable levels of risk aversion. Benartzi and Thaler (1995) and Barberis, Huang, and Santos (2001) demonstrate how a model of loss aversion can be consistent with the observed historical equity premium. Note, however, that both of these papers make a rather different assumption about the coding of gains and losses: they assume that investors experience gain/loss utility each time they check their portfolio. This highlights the degree of freedom to make assumptions about how people define gains and losses.

One dimension on which the alternative models of risk aversion can make very different predictions from expected utility is participation in stock markets. Under expected utility, a well-known result is that anyone who is saving wealth for the future should invest at least some of that wealth in risky assets. As mentioned earlier, starting from no risk (investing everything in the risk-free asset), the cost of taking on a little risk (investing some in the risky asset) is second order, while the benefit from the higher expected return on risky assets is first order. In contrast, under loss aversion with an endogenous reference point or under probability weighting, the cost of taking on a little risk is first order, and as a result it can be optimal for a person to strictly prefer investing all wealth in the risk-free asset. Empirically, a large fraction of individuals do not participate in stock markets (for instance, Bertaut 1998).

Barberis and Huang (2008) develop in detail the implications of probability weighting for the pricing of skewed assets. For assets with positively skewed returns, the small chance of a large payoff is overweighted, inducing risk-seeking behavior. Investors are therefore willing to accept a negative excess return to invest in these assets. Barberis and Huang (2008) argue that this intuition offers a unified explanation for a number of puzzles in the finance literature: stocks that recently went through an initial public offering, options that are far from their strike price, distressed assets, and private equity all display positively skewed returns, and hence are prone to pricing "anomalies" if these phenomena are viewed from the perspective of expected utility. Recently, some of these predictions have received empirical support (for instance, Boyer, Mitton, and Vorkink 2010; Green and Hwang 2012).

Finally, we mention the potential for models of context-dependence and salience in this domain. Most of the work on such models does not yet seriously address financial market implications. However, Bordalo, Gennaioli, and Shleifer

(2013) emphasize how salience can provide a psychological grounding for a preference for skewness. They further describe how it can provide an intuitive account of the growth-value puzzle, which refers to the empirical finding that stocks with low market prices relative to fundamentals ("value stocks") command an above-average return, while stocks with high prices relative to fundamentals ("growth stocks") earn below average returns (Fama and French 1992). Bordalo et al. suggest that the unlikely upside of a growth company becoming a market leader attracts attention, while the small possibility of a value stock going bankrupt also attracts attention. They also suggest that salience offers a unique account for the empirical finding that risk premiums vary over time (Campbell and Shiller 1988). In particular, Bordalo et al. suggest that in booms, the upside of the market is salient, prompting risk-seeking behavior and overvaluation, whereas in busts, the downside weighs on investors' minds, causing them to become risk-averse and undervalue the market. These speculations are intriguing, but clearly more work needs to be done.

Reconsidering Principal–Agent Relationships

In the principal–agent paradigm in which a risk-neutral principal hires a risk-averse agent to complete a task—as with a landlord and a tenant-farmer—alternative models of risk aversion can easily generate the same general trade-off between incentives and insurance that arises from expected utility. Imposing risk on the tenant remains necessary to generate incentives. An agent who dislikes that risk, for whatever reason, will demand to be compensated.

Much as for the domains of insurance and financial investment, loss aversion with an endogenous reference point would clearly generate such risk aversion. Probability weighting could also generate it, depending on the specific probabilities. If the states with low crop yield—and therefore low compensation—are overweighted, the tenant will demand to be compensated for the risk. If instead those states are underweighted, then the landlord can in fact take advantage of the tenant's probability weighting to pay an expected compensation that is less than the agent's reservation wage.

Yet again, the potential value of alternative models lies in whether they make better predictions for more complex behaviors. Indeed, attempts to take the basic principal–agent model based on expected utility to data have not been especially successful: factors that one might expect to moderate the strength of incentives—such as the noisiness of the relationship between effort and output, the marginal return to effort, and the degree of risk aversion of agents—seem to have little predictive content. As a result, the agency literature has turned its focus in other directions that rely less on risk aversion as a limit on incentives: for example, to concerns about multi-tasking and the inefficient allocation of effort across types of tasks (for overviews, see Prendergast 1999, and in this journal, Gibbons 1998). While such analyses have been successful, some recent work suggests that there might be value to turning to behavioral approaches to contract theory, as reviewed in depth by Kőszegi (2014). Alternative models of risk aversion are but one of a range of perspectives that have been offered in this literature.

One example of the potential gains from such an approach revolves around what is sometimes known as the "paradox of simple contracts." A classic result in agency theory (based on expected utility) is that the optimal contract should make use of any observable that reveals information about the agent's otherwise unobserved choice of effort (Hölmstrom 1979). For instance, in our landlord-tenant example, if there are many possible realizations of crop yield, and if increased effort shifts the distribution of crop yields towards higher amounts, then the optimal contract should involve a compensation level that fully depends on crop yield. In other words, the theory predicts that contracts should be complex. In practice, however, we often see very simple contracts—for example, the dependence on crop yield might be simplified to a small number of possible compensations.

Herweg, Müller, and Weinschenk (2010) demonstrate that, in fact, loss aversion with an endogenous reference point can make simple contracts optimal. Specifically, they rely on a feature of the Kőszegi and Rabin (2006, 2007, 2009) approach wherein the reference point can in fact be a reference lottery, and the person compares the realized outcome to each outcome that was possible in the reference lottery. With this structure, the more risk there is in the reference lottery, the more disutility there is from loss aversion. Herweg et al. show that, even when many different outcomes are possible, the optimal contract can in fact be a binary contract in which the agent gets a high wage if output is large enough, and otherwise gets a low wage. Intuitively, there must be at least two wage levels to generate incentives for effort, but adding additional wage levels only creates the possibility of additional disutility from loss aversion.

Another example relates to firms' use of stock options. In this journal, Hall and Murphy (2003) note that the prevalence of stock options in compensation packages is puzzling from the perspective of expected utility because standard risk aversion implies that employees should value options below their market price, making them an expensive way of providing incentives. Using data on compensation packages for 598 chief executive officers, Dittmann and Maug (2007) show that to (partially) account for observed stock option holdings, agents need to exhibit very low risk aversion. However, such low risk aversion also predicts a negative base salary. Spalt (2013) argues that probability weighting offers an intuitive explanation for why firms issue so many stock options. Specifically, stock options typically involve a small chance of a large return, and if agents overweight this possibility, stock options become a cheap method for firms to incentivize their workers.

Finally, recent work on context-dependence and salience might also shed light on why strongly incentivized contracts are so unpopular. Bushong, Rabin, and Schwartzstein (2017) argue that agents might be less likely to exert effort when incentives create significant income uncertainty. Intuitively, by generating a wide range of potential incomes, such incentives have the perverse effect of making effort especially salient, causing agents to underweight these monetary incentives. While this result depends on the specific assumptions about salience, it highlights the potential value context-dependence risk preferences offer.

Discussion

This article has had three main goals: 1) to highlight that the basic intuition of risk aversion driving many results in economics is not intimately tied to expected utility, 2) to describe some alternative models that can also capture the basic intuition of risk aversion, and 3) to discuss how, for more complex behaviors, these alternative models might better explain some observed phenomena (than does expected utility). Much work remains to be done, and we conclude by discussing some broader issues related to this agenda.

Rabin (2013) emphasizes the importance of "portable models" that can easily be applied in a broad set of economic applications. It is also important that models be tractable so that they can be extended from simpler to more complex settings. Expected utility fares well on both dimensions: it is a simple and straightforward model with few degrees of freedom. Alternative models of risk aversion currently fare less well.

Early models of loss aversion were fairly simple and tractable, but they weren't entirely portable. In particular, in each application, one had to—or, more to the point, one was permitted to—make application-specific assumptions about the determinants of gains and losses. The Kőszegi and Rabin (2006, 2007, 2009) approach to loss aversion with an endogenous reference point attempted to reduce this degree of freedom by imposing that the reference point is fully determined by one's expectations about outcomes. But this approach comes at the expense of some tractability, and there is still some flexibility in what one assumes about the source of expectations. Moreover, there might be reference points that are unrelated to expectations. For instance, people might also define gains and losses relative to past outcomes, as in the dynamic model of job search in DellaVigna, Lindner, Reizer, and Schmieder (2017). Or people might define gains and losses relative to certain focal outcomes, as in the finding of Rees-Jones (forthcoming) that a zero balance due seems to be a focal reference point for tax filers. A more systematic understanding of when these various reference points are appropriate is necessary for richer, more portable, characterizations of loss aversion.

In principle, probability weighting appears to be a portable and somewhat tractable model. However, it runs into issues in applications where one must simplify the state space: for example, when one assumes for tractability a coarser set of outcomes than might really be relevant. While such simplifications are relatively innocuous in the expected utility model, decisions on how to simplify the state space can have a big impact with nonlinear probability weighting. Furthermore, the psychology of probability weighting is poorly understood.

Models of context-dependence and salience may provide a better foundation for when, and why, probabilities are re-weighted. In their current form, however, there is no agreed-upon definition of salience or what aspects of the choice environment grab attention. As an additional layer of complexity, expectations, previous choice sets, or options available elsewhere may be an integral part of the "context" for the current choice. While we are optimistic that such models might yield new

insights into the nuances of risk preferences, much empirical evidence and theoretical endeavor is required.

Alternative models of risk aversion require us to rethink how we conduct welfare analysis and make policy recommendations. In simple terms, we have already highlighted how alternative models can yield different behavioral predictions, which is of course relevant for welfare analysis. Indeed, these models suggest new policy levers that one might have thought unimportant when viewed through the lens of expected utility—for instance, policies that require bundling (or unbundling) of risks in ways that change the perception of gains and losses, the relevant probabilities, or the broader context could have significant impacts on behavior. Beyond the behavioral predictions, a perhaps even more important issue arises: the psychology of the alternative models suggests that the model that describes people's behavior might not be the metric we ought to use for welfare analysis. Such a distinction between "decision utility" and "experienced utility" was first discussed by Kahneman (1994), and there continues to be a debate about how best to approach this distinction (for some thoughtful discussions, see Kahneman and Thaler 2006; Kőszegi and Rabin 2008; Bernheim and Rangel 2009).

An important direction for future research is to apply alternative models of risk aversion in dynamic models of risky choice. Some prominent situations of risk aversion have an intertemporal dimension, including savings and consumption problems, dynamic labor supply decisions, and health decisions. So far, there has been limited progress in taking alternative models to dynamic settings. A notable exception is Kőszegi and Rabin (2009), who define loss aversion over changes in beliefs regarding both current and future consumption. A number of novel insights emerge from these risk attitudes, and Pagel (2017, forthcoming) shows that they combine to offer a unified explanation for a number of seemingly disparate puzzles. But these papers are just the first steps in this area.

Real-world risk aversion is clearly not as straightforward as expected utility suggests. Perhaps most notably, we don't even always observe risk aversion, as in some situations individuals systematically exhibit risk-seeking behavior. At horse races and in casinos, people actively make bets in a domain where virtually all bets have a negative expected payoff. In experiments, people are often risk seeking when considering simple binary gambles with a moderate probability of a loss, or with only a small probability of a gain. If we want a portable model that can explain behavior across domains, simple expected utility will not work. Additional sources of risk aversion (or risk seeking) need to be used instead of, or in conjunction with, diminishing marginal utility of wealth. The alternative models discussed here might not ultimately prove to be the best models for studying risk aversion, but they are useful steps in what we hope will be an ongoing search.

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