LOSS AVERSION: AN EVOLUTIONARY PERSPECTIVE

Abstract

Loss aversion is a central element of modern theories of choice. While loss aversion has been extensively documented experimentally and empirically, and is employed to explain important economic phenomena such as the equity premium, its origins are not yet well understood. We suggest that loss aversion is a consequence of the evolutionary objective of minimizing the probability of extinction of one's line of descendants. A simple relationship is derived between the equilibrium loss aversion coefficient and the extinction probability. Empirical estimates of the extinction probability imply a loss aversion coefficient of 2.17, a value close to the estimates obtained experimentally.

Keywords: *loss aversion, preference, evolution, extinction, having descendants forever.*

JEL classification: D81, D03.

1. Introduction

One of the key elements of Prospect Theory is that the choice among risky prospects is based on the change of wealth, rather than on the total wealth. In addition, gains and losses are evaluated differently, and losses are overweighed relative to gains of the same magnitude (Kahneman and Tversky 1979, Tversky and Kahneman 1992). These two properties are captured by the following streamlined value function introduced by Benartzi and Thaler (1995):

$$V(x) = \begin{cases} x & \text{for } x \geq 0 \\ \lambda x & \text{for } x < 0 \end{cases} \tag{1}$$

where x is the change of wealth relative to the current wealth, λ is the loss-aversion coefficient, and the objective is the maximization of $E[V(x)]$.[1] An individual with these preferences is indifferent to a gamble with a 50% probability of losing \$1 and a 50% probability of gaining $\$\lambda$. Loss aversion implies $\lambda > 1$, i.e. losses are weighed more heavily than gains. Experimental and empirical studies typically estimate λ to be in the range 1.81-2.61 (see Table I).

(Please insert Table I about here)

The evidence for loss aversion is overwhelming. Loss aversion is generally inconsistent with the standard expected utility framework, in which choice is based on total wealth, and it has numerous implications for economics, psychology, sociology, marketing and even politics. For example, Benartzi and Thaler (1995) show that loss aversion can provide an explanation for the equity premium puzzle. The combination of loss aversion and myopia have a dramatic affect on savings behavior (Gneezy and Potters (1997), Benartzi and Thaler (1999), and Haigh and List (2005)). Barberis and Huang (2001) and Berkelaar, Kouwenberg, and Post (2004) derive the implications of loss aversion for optimal portfolio choice and for stock returns. Hardie, Johnson, and Fader (1993) and Ho and Zhang (2008) study the implications of loss aversion for marketing. Genesove and Mayer (2001) examine the effects of loss aversion on housing markets. Jervis (1992) analyzes the political implications of loss aversion. Rabin (2000) and Rabin

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[1] In addition to loss aversion, Prospect Theory also implies risk-aversion for gains and risk-seeking for losses (i.e. $V(x)$ that is concave for $x>0$ and convex for $x<0$), and also allows for subjective probability weighting. As our focus in this paper is loss aversion, we abstract from these features to simplify the analysis and we employ the Benartzi and Thaler (1995) piecewise linear value function.

and Thaler (2001) show that loss aversion offers a solution to a paradoxical set of choices that arises in the expected utility framework.

While loss aversion is a cornerstone of the current theory of choice, very little is known about the origin of this behavior. Choices between risky alternatives are probably affected by education, age and life experience. However, more and more evidence is accumulating about the central role of genetics in determining preferences. For instance, empirical studies have shown that the asset allocation of identical twins are much more correlated than those of twins who are not identical. Furthermore, the asset allocations of identical twins who where raised apart are also highly correlated (see Cesarini et. al. 2009, 2010, and Barnea, Cronqvist, and Siegel 2010). In recent years biologists and economists have identified specific "risk-attitude" genes (see Kuhnen and Chiao 2009, and Zhong et. al. 2009). If preferences are (at least partially) genetically determined, one can view the observed loss aversion as the result of an evolutionary process selecting for the evolutionary most advantageous risk attitude.[2] This is the idea followed in the present paper. While there is a rapidly growing literature on the evolution of preferences, most of these studies analyze the implications for risk aversion, time preference, and group effects.[3] In contrast, the focus of the present paper is on loss aversion.

In the next section we discuss several possible evolutionary objective functions, with a special emphasis on the objective of "having descendants forever", i.e. the objective of not having one's line of descendants cut-off. While there is no single objective function that is dominant over all others, evolutionary biologists argue that the having-descendants-forever objective has likely played a central role in human evolution. In Section 3 we develop the implications of this evolutionary objective function to risky choice. We show that it implies basing choices on change in wealth rather than total wealth, exactly as found in Prospect Theory. It also yields loss aversion. Furthermore, we develop a simple theoretical relationship between the equilibrium loss aversion coefficient λ and the probability of extinction of one's line of descendants. In Section 4 we examine this theoretical relationship by comparing the empirical extinction probabilities reported in the literature with the estimates of λ. Perhaps surprisingly, we

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[2] It is interesting to note that loss aversion has been documented not only in humans, but in monkeys as well (Chen, Lakshminarayanan, and Santos 2006). Tom, Fox, Trepel, and Poldrack (2007) identify specific regions in the brain that correspond to loss averse behavior.

[3] A comprehensive review of this literature is beyond the scope of this paper. An excellent overview of the literature of the evolution of preferences can be found in Robson and Samuelson (2010).

find good agreement between these apparently completely unrelated parameters. Section 5 concludes.

2. The Evolutionary Objective Function

In an evolutionary context, organisms can be viewed as vessels for carrying their genes (Dawkins 1989). Genes are "successful" if they manage to perpetuate from one generation to the next. Thus, one possible evolutionary "objective function" that can be considered is the maximization of the expected number of offspring – the more offspring, the more copies of the organism's genes are transmitted to the next generation. While this is a simple and intuitively appealing objective function, it may lead to unreasonable results. To illustrate, consider the following simplified example. Suppose that there are only two possible reproduction prospects or "gambles" to choose from. Gamble A yields 0 offspring with probability 0.3 and 2 offspring with probability 0.7. Gamble B yields 0 offspring with probability 0.8 and 9 offspring with probability 0.2. Suppose also that there are two types of preference genes: gene A that implies the preference of gamble A, and gene B that implies the preference of gamble B.[4] Assume that the gamble realizations are independent across individuals.[5] Then, after T generations the expected number of individuals with gene A will be $\left(0.3\cdot 0+0.7\cdot 2\right)^T=1.4^T$, while the expected number of individuals with gene B will be 1.8^T. Clearly, after some time the expected number of individuals with gene B becomes much larger than that of gene A, and the ratio of the expected numbers goes to infinity as $T\to\infty$. This may be interpreted as "B dominates the population in the long run", and it is the motivation for the criterion of maximizing the expected number of offspring.

However, it is far from obvious that this criterion is evolutionary advantageous. Note that in the above example population B has a much larger probability than population A of becoming completely extinct. Let us elaborate. A direct calculation of the probability that A's line becomes extinct is quite cumbersome, because there are infinitely many possible realizations that lead to extinction.[6] Fortunately, it is much easier

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[4] As is typical in this literature, reproduction is assumed to be asexual, i.e. the offspring have the same preferences as their parent.

[5] In addition to this idiosyncratic randomness, individuals and species may also be exposed to "macro" or aggregate environmental risk. Robson (1996) and Brennan and Lo (2011) provide illuminating discussions of aggregate risk effects.

[6] For example, one possible scenario for extinction is that the original parent has two offspring, each one of these offspring has two offspring, but in the third generation all four offspring die. Of course, there are

to solve this problem recursively. Let us denote the probability that the line of descendants of an individual with gene A will become extinct by x_A. It is possible, with probability 0.3, that the initial individual will have no offspring, and this will imply the end of his line of descendants. However, even if he survives to have 2 offspring, (and this occurs with probability 0.7), it is possible that the lines of both of these offspring will eventually become extinct. As the offspring carry gene A, for each one of them the probability that *his* line of descendants will eventually become extinct is also by definition x_A. As the gambles are assumed to be independent, the extinction of one offspring is independent of the extinction of the other, and therefore the probability that both lines eventually become extinct is x_A^2. Thus, x_A is the solution to:

$$x_A = 0.3 + 0.7x_A^2, \tag{2}$$

which yields $x_A = 0.428$. This value captures all of the possible scenarios leading to eventual extinction. The probability of A Having Descendants Forever, $p_A(HDF)$, is the probability that A's line of descendants does *not* become extinct, and it is given by $p_A(HDF) = 1 - x_A = 0.572$. Similarly, the probability that individual B's line of descendants eventually becomes extinct is given by the solution to:

$$x_B = 0.8 + 0.2x_B^9. \tag{3}$$

Solving eq.(3) numerically yields $x_B = 0.843$, which implies $p_B(HDF) = 1 - x_B = 0.157$.[7] Thus, while the ratio of the expected population of A to the expected population of B converges to zero as $T \to \infty$, type A has a much higher probability of surviving forever. How can these two facts be reconciled? Note that as T becomes large the probability distribution of the number of B descendants becomes very skewed – there is a large probability that B will become extinct, but there is a small probability that B will have a very large number of descendants. This extreme low-probability event drives the high expected value of B descendants.

Extinction plays an obvious central role in the evolutionary dynamics. One may suspect, though, that once the population of a given type reaches a certain size, the probability of extinction in the i.i.d. reproduction framework is negligible. However, evolutionary biologists show that the p(HDF) criterion may be very important even after

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infinitely many such scenarios leading to extinction, and the probability of eventual extinction, x_A in the notation below, is the sum of probabilities for all these events.

[7] Equations (2) and (3) are special cases of the general Galton-Watson (1875) equation for the probability of extinction of a family line.

the number of individuals in each preference type has become large, for at least three reasons: i) genetic diversity[8], ii) population "bottlenecks"[9], and iii) the "founder effect"[10].

Another evolutionary objective function suggested in the literature is the geometric mean growth rate. Note, however, that this criterion is applied to the growth rate of the entire population, rather than to individual choice, and these two frameworks can be very different, depending on the correlation between the individuals. Moreover, if there is *any* probability of extinction, the geometric mean is 0, and the comparison of gambles becomes meaningless.

Each of the different evolutionary objective functions employed in the literature has its pros and cons. Evolutionary biologists argue that the p(HDF) objective plays a central role (see, for example, Cohen 1993, and references therein). We do not presume to determine that maximizing p(HDF) is the "correct" objective function, nor that it is the only one that should be considered. Our standpoint is that the p(HDF) criterion likely plays an important role in the evolutionary process, and should therefore be given careful consideration. This is the path followed in this paper. The viewpoint that *both* the number of descendants and the p(HDF) are important is beautifully captured by the following biblical blessing:

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[8] Consider, for example, the types A and B discussed above. Suppose that there are 100 individuals with risk preference gene A, and 100 individuals with gene B. Furthermore, assume that individuals carry many other genes in addition to the risk preference gene, i.e. each individual represents a unique combination of genes (or alternatively, each "individual" actually represents a sub-type). After many generations, out of the 100 sub-types carrying gene A, on average 57.2 will survive (recall that $p_A(HDF) = 0.572$) . In contrast, out of the initial 100 sub-types carrying gene B, on average only 15.7 will survive. Thus, the preference for higher p(HDF) maintains more genetic diversity, which is an obvious evolutionary advantage. For example, environmental conditions may drastically change, making only a very small number of sub-types viable. The type with more genetic diversity has a higher probability to survive such a change.

[9] When viewed in a short-run perspective, populations usually grow at rather steady rates. However, when viewed at a longer-run perspective, the population size sometimes changes abruptly and dramatically, typically due to changes in the environmental conditions. There are known instances where populations that were very large underwent drastic declines, reaching the verge of extinction. If extinction is eventually avoided, these episodes are called "population bottlenecks". Evolutionary biologists believe that the human population experienced a population bottleneck some 60,000-70,000 years ago, a rather short time in evolutionary terms, possibly due to the eruption of the Toba super-volcano in Indonesia (see Ambrose 1998, Hawks et. al. 2000, and Dawkins 2004). This may explain the fact that all human males can trace their ancestry back to a single male, the so-called "Y-chromosomal Adam" that lived around 60,000 to 90,000 years ago (Dawkins 2004). Clearly, in a near-extinction situation maximization of p(HDF) becomes a very important evolutionary objective function: the family lines that survived the bottleneck are likely those with genes "programmed" to maximize the probability of having descendants forever (Cohen 1993).

[10] This effect refers to the situation where a small group becomes separated from the main population, and explains, for example, the very limited gene pool in Iceland, or the extraordinarily high percentage of deaf individuals in Martha's Vineyard (Mayr 1959).

> *Your descendants would have been like the sand, your children like its numberless grains; their name would never be cut off nor destroyed from before me.*
>
> Isaiah 48:19

This blessing is composed of two parts: the first is the promise of many descendants (like the number of grains of sand); the second is the promise of Having Descendants Forever (their name would never be cut off). The two parts have different meaning, and both parts are important.

To the best of our knowledge, the first to introduce the concept of HDF to economics was Meginniss (1977), who analyzed p(HDF) in the framework of a constant birth probability per unit time and a constant death probability per unit time. Perhaps surprisingly, in the long time that has passed since Meginniss's innovative work, the p(HDF) criterion has not received much attention[11]. The purpose of this paper is to develop the concept of p(HDF) in a general setting, and to examine the implications of this criterion for the evolutionary foundations of loss aversion.

3. Loss Aversion and Minimization of the Extinction Probability

From an evolutionary standpoint, the objective function is defined in terms of the number of offspring. Standard economics defines utility in terms of consumption. Of course, there is a close relation between consumption and the number of offspring – the more resources at an individual's disposal, the more offspring s/he can raise. While the exact relation between the level of consumption and the number of offspring is not obvious, here we adopt the standard, and the most simple, assumption that raising each offspring requires a certain level of consumption, *C*, and hence the number of offspring is proportional to consumption[12].

Consider an individual with *N* existing offspring, each of which has a probability *x* of having his line of descendants eventually becoming extinct. The individual faces a probability of x^N that his line of descendants will become extinct (i.e. p(HDF)=1-x^N ; as

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[11] A few exceptions are Lesourne (1977) and Rubin and Paul (1979).

[12] This assumption clearly does not hold in modern human societies, where the relationship between wealth and number of offspring is often reverse. However, it is probably a reasonable approximation for the era during which our preferences have evolved, and indeed, this is the assumption made in most studies. For example, Sinn (2003) writes: "… it is assumed that the number of children a parent has is proportional to the amount of resources he commands".

before, we assume independence across offspring). Now, the following risky gamble presents itself: gain *m* additional offspring with probability p_m, *m*-1 additional offspring with probability p_{m-1}, …, lose *k* offspring with probability p_{-k}. I.e. the gamble is: $(p_m, m; p_{m-1}, m-1; \ldots p_0, 0; p_{-1}, -1; \ldots \quad p_{-k}, -k)$.[13] From the perspective of minimizing the probability of extinction, when should such a gamble be accepted? Without the gamble the probability of extinction is x^N. With the gamble, there is a probability of p_m for having *N*+*m* offspring, a probability of p_{m-1} for having *N*+*m-1* offspring, etc., and therefore the extinction probability is: $p_m x^{N+m} + p_{m-1} x^{N+m-1} + \ldots p_{-k} x^{N-k}$. Thus, the gamble should be accepted if and only if:

$$p_m x^{N+m} + p_{m-1} x^{N+m-1} + \ldots p_{-k} x^{N-k} \quad < \quad x^N, \tag{4}$$

or:

$$p_m x^m + p_{m-1} x^{m-1} + \ldots p_{-k} x^{-k} \quad < \quad 1. \tag{5}$$

Equation (5) implies that the decision about the gamble is independent of the number of existing offspring, *N*. This result has a profound implication. Just as in the Prospect Theory framework a gamble is evaluated based on the *change* of wealth, independently of the existing wealth, in the evolutionary framework we find the same result: gambles are evaluated based on the change in the number of offspring, independently of the existing number. This suggests an evolutionary basis for the experimentally revealed reference-point behavior as described by Prospect Theory.

We would like to go further, and relate the loss aversion coefficient, λ, to the evolutionary objective function. Note, however, that there is no analytical solution to the criterion for a general gamble as described in eq.(5). Hence, we will restrict ourselves to a more basic gamble which can be treated analytically. Namely, consider a gamble by which there is a probability *p* of gaining one additional offspring, and a probability of 1-*p* of losing one offspring. In this case, eq.(4) becomes: $px^{N+1} + (1-p)x^{N-1} \quad < \quad x^N$, and eq.(5) becomes $px + (1-p)x^{-1} \quad < \quad 1$, or:

$$px^2 - x + (1-p) < 0, \tag{6}$$

which yields:

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[13] As the number of offspring can not be negative, we have a restriction *k*<*N*.

$$\frac{1}{1+x} < p .^{14} \tag{7}$$

Thus, the gamble should be accepted if and only if the success probability exceeds $\frac{1}{1+x}$, where *x* is the probability of eventual extinction for each offspring.

Note that for $p \leq 1/2$ the gamble is refused for any value of $0 < x < 1$, i.e. if the gamble is fair (or worse) it is refused, in line with the notion of loss aversion. Eq.(7) implies that the smaller *x* is, the larger the probability *p* required to make the gamble acceptable. The intuition for this is as follows. An addition of one offspring increases p(HDF) less than the reduction of one offspring diminishes it. This is why a fair gamble is not accepted, and why *p* must be larger than 1/2 for the gamble to be accepted. If *x* is close to 1, the difference between x^{n-1} and x^{n+1} is not very large, and therefore *p* does not have to exceed 1/2 by much. However, if *x* is small the above difference is (relatively) large, and *p* must be large to compensate. In other words, when most offspring are likely to have descendants forever, an additional offspring does not contribute much to p(HDF), but a reduction of one offspring does have a large effect on p(HDF). Thus, a large *p* is required to make the gamble acceptable.

How would the above gamble be evaluated in the Prospect Theory framework? Given that an additional offspring corresponds to an additional consumption of *C*, and that a loss of an offspring corresponds to *–C*, the value function (1) implies that the gamble should be accepted if and only if:

$$pC - (1-p)\lambda C > 0 , \tag{8}$$

or:

$$\frac{\lambda}{1+\lambda} < p . \tag{9}$$

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[14] The expression on the r.h.s. of eq.(6) is an upward facing parabola, so the *x*'s solving eq.(6) are those between the two roots of the equation $px^2 - x + (1-p) = 0$. These roots are:

$$x_{1,2} = \frac{1 \pm \sqrt{1-4p(1-p)}}{2p} = \frac{1 \pm \sqrt{(2p-1)^2}}{2p} = \frac{1 \pm (2p-1)}{2p} \Rightarrow x_1 = \frac{1-p}{p} \quad x_2 = 1.$$ Thus, any *x* in the relevant range *0<x<1* that satisfies $x > (1-p)/p$ also satisfies eq.(6). Rearranging, we obtain: $\frac{1}{1+x} < p$.

Comparing eqs.(7) and (9) reveals that $\frac{1}{1+x}$ in the evolutionary framework plays the role of $\frac{\lambda}{1+\lambda}$ in the Prospect Theory framework. Simplifying the relation between x and λ, we obtain: $\frac{1}{1+x} = \frac{\lambda}{1+\lambda} \quad \Rightarrow$

$$x = \frac{1}{\lambda}. \tag{10}$$

Hence, $\frac{1}{x}$ plays the role of the loss-aversion parameter λ. The value of λ has been experimentally and empirically estimated to be approximately 2.2 (see Table I). In the next section we discuss the empirical estimates of the extinction probability x that appear in the literature, and evaluate the theoretical relation between λ and x developed above.

4. Empirical Estimates of the Extinction Probability

The probability of a human family line becoming extinct was discussed as early as 1845 by Bienaymé, who analyzed the extinction of noble families, and later by de Candolle (1873), Galton and Watson (1875), Lotka (1931), Steffenson (1933), and Kolmogorov (1931) (for an excellent review of the literature on this subject see Albertsen (1995)). The most rigorous empirical analysis of the extinction probability was conducted by Keyfitz and Tyree (1967) and Keyfitz (1968) who estimate the extinction probability by employing statistics on the probability p_i of having *i* children. They use these probabilities to find the extinction probability as the solution to the Galton -Watson (1875) equation[15].

Keyfitz and Tyree (1967) and Keyfitz (1968) estimate the extinction probabilities for family lines in two developing countries (Mexico and Israel), and three developed countries (U.S., Hungary, and Japan).[16] The values they find are reported in Table II. The developing countries are presumably closer to the environment in which preferences

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[15] The Galton-Watson equation is given by: $x = p_0 + p_1 x + p_2 x^2 + \ldots + p_m x^m$ where p_i is the probability of having *i* offspring and x is the probability that the line of descendants eventually becomes extinct. This equation is a generalization of equations (2) and (3) employed to solve for the extinction probabilities in the specific examples of Section 2.

[16] This is the country categorization at the time corresponding to the sample period of the Keyfitz and Tyree study. See http://www.census.gov/population/international/data/idb/country.php.

have evolved over the long history of human evolution. The average extinction probability for the developing countries is $x = 0.46$.

This value corresponds by the theoretical prediction of eq.(10) to a loss aversion coefficient of $\lambda = \frac{1}{x} = \frac{1}{0.46} = 2.17$.[17] This value is very close to the value of $\lambda = 2.20$, which is the typical estimate for the loss aversion coefficient obtained in the very different experimental framework of Prospect Theory (see Table I). It is encouraging and perhaps even surprising that we obtain values that are so similar from two completely different and independent approaches.

(Please insert Table II about here)

5. Conclusion

While most studies take preferences as exogenously given, an innovative strand of the economics literature suggests viewing preferences as the result of the process of evolution. In this literature the number of offspring is typically assumed to be proportional to the level of consumption, and thus there is a correspondence between consumption gambles and gambles on the number of offspring. Most of the studies in this strand take the evolutionary objective function as the maximization of the expected number of offspring, or alternatively, as the maximization of the geometric mean growth rate of the entire population. While these objectives are appealing and intuitive, in this paper we suggest that careful consideration should also be given to another evolutionary objective function advocated by evolutionary biologists: minimizing the probability of extinction of one's line of descendants (or, equivalently, maximizing the probability of Having Descendants Forever, p(HDF)). This objective captures elements that likely play an important role in the evolutionary process, and are absent in the more standard objective functions.

We show that maximizing the probability of Having Descendants Forever implies loss aversion. The criterion for accepting/rejecting a reproduction gamble in the evolutionary framework is independent of the number of existing offspring, which can explain why wealth (or consumption) gambles are evaluated independently of current

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[17] For the developed countries the average extinction probability is somewhat higher at $x = 0.63$ (because in the developed countries the average number of children is lower than in the developing countries). This value corresponds to a lower loss aversion coefficient of $\lambda = \frac{1}{0.63} = 1.59$. Note, however, that the environmental conditions in developed countries are probably representative only of the last few decades, before which they likely resembled those in developing countries.

wealth in the Prospect Theory framework. Moreover, we find a simple theoretical relationship tying the equilibrium loss aversion parameter, λ, with the probability of extinction of one's line of descendants, *x*: $\lambda = \frac{1}{x}$.

Empirical estimates of the family-line extinction probabilities in developing countries yield an average value of $x = 0.46$. This corresponds to a loss aversion parameter of $\lambda = \frac{1}{0.46} = 2.17$. This value is very close to the experimental and empirical estimates of λ, which are typically in the range 2.1-2.3. While various caveats obviously apply, it is quite surprising and encouraging to find such an agreement between these two *a-priori* completely unrelated parameters, from two different scientific areas.

These findings suggest an evolutionary explanation for the experimentally and empirically observed loss aversion. The evolutionary origin of loss aversion may be further explored via several different paths. First, it may be possible to identify the exact gene responsible for loss aversion behavior, directly demonstrating that loss aversion is (at least partially) a genetically transferable trait. It may also be possible to find secluded populations that have developed in different environmental conditions with different extinction probabilities, and to examine whether the different probabilities also correspond to different average degrees of loss aversion across the different populations. Finally, agent-based simulation studies of the evolution of a heterogeneous population may shed light on the time it would take for the equilibrium loss aversion parameter to arise as a result of the evolutionary process.

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Table I

Experimental and empirical estimates of the loss aversion parameter, λ. All of the studies below are experimental, except Levy (2009) which is based on empirical data of risk and return parameters in international capital markets. See Abdellaoui, Bleichordt, and Paraschiv (2007) for alternative definitions and methods of estimating loss aversion.

	λ
Kahneman, Knettsch, and Thaler (1990)	2^+
Tversky and Kahneman (1991)	2^+
Kahneman and Tversky (1992)	2.25
Pennings and Smidts (2003)	1.81
Abdellaoui, Bleichordt, and L'Haridon (2008)	2.61
Levy (2009)	2.3

Table II

The probability of a person's line of descendants eventually becoming extinct, x, for different countries, as estimated by Keyfitz and Tyree (1967) and Keyfitz (1968). The average value for the developing countries (shaded) is $x=0.46$.

Mexico	0.4066
Israel	0.5144
USA	0.8206
Hungary	0.7130
Japan	0.3242