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Risk Appetite

Summary: Our article firstly examines to what extent empirical research confirms the model of decision making based on a stable utility function. To this end, we have summarised the fundamental theoretical correlations relating to risk appetite, then went on to present the main results of behavioural research, with special focus on prospect theory, the correlations between socio-demographic and cognitive characteristics and risk propensity, as well as other influencing physical, mental and psychological factors. Our other research question based on this was whether there are accepted theoretical and methodological guidelines as to what methods an advisor should employ to become familiar with the customer's risk-taking behaviour and how the subsequent advisory process should be conducted. We first reviewed the methods used in international practice to determine risk appetite as well as the criticisms these drew in relevant literature and then determined that for the time being, in advisory practice not only is it unclear which method is most suitable to gauge investors' risk appetite, but also to what extent the advisor must accept or direct the customer's risk preferences during the establishment of the investment strategy.[1]

Keywords: risk appetite, risk aversion, utility theory, prospect theory
JEL code: G11

The theoretical and practical literature on risk management, and, accordingly, university curriculum as well, focuses primarily on the measurement of risk, and the technical details of hedging and insurance strategies. In standard micro-economic theory, risk preferences (risk appetite, risk tolerance, risk propensity, risk aversion, etc.) are given, clearly existing external features, which are never called into doubt as long as they behave well from a mathematical perspective so that we can base optimisation on them.[2]

As a consequence of results in behavioural finance as well as the most recent regulatory developments, however, focus clearly shifted to risk preferences. This prompted advisory practice to react by implementing and improving models to assess risk appetite. In our article, we first provide a brief summary of utility theory, followed by the results of behavioural finance, then review the characteristics of practical models that serve to measure risk appetite.

RISK APPETITE IN UTILITY THEORY[3]

Securities that provide a w_1 amount to the holder with probability p and a w_2 amount with probability $(1–p)$ are called risky payments or prospects. These prospects, as risky securities, differ from one another in terms of parameters, and there is a given investor who is looking for the optimal portfolio. In order to solve this problem, the investor must first rank these prospects according to how attractive these are to him/her (preference ordering).

It has been proved (von Neumann and Morgenstern, 1944), that if the investor's preference ordering fulfils certain axioms (completeness, reflexivity, transitivity, continuity and strict monotony), then there exists a continuous utility function that repre-

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sents the given investor's preference ordering. Of course, all monotonic transforms of this continuous function may equally be considered the investor's utility function. It has also been proved that if certain other conditions are met, there is a monotonic transformation that helps us arrive at a special utility function which has the so-called expected utility feature (von Neumann, Morgenstern, vNM utility function):

$$u(prospect)=pu(w_1)+(1-p)u(w_2)$$

In other words, a vNM utility function may be clearly constructed for every well-behaving preference ordering.[4] In essence, rationality means that the investor's decisions can be traced back to such a vNM utility function.[5]

A direct relationship can be established between the shape of the utility function and risk propensity, as shown in *Chart 1*.

The more concave the investor's vNM utility function, the more he may be considered risk averse. So-called local risk aversion in point w can be measured using the Arrow-Pratt measure of risk aversion, which is a standardised indicator of the concavity of the utility function:[6]

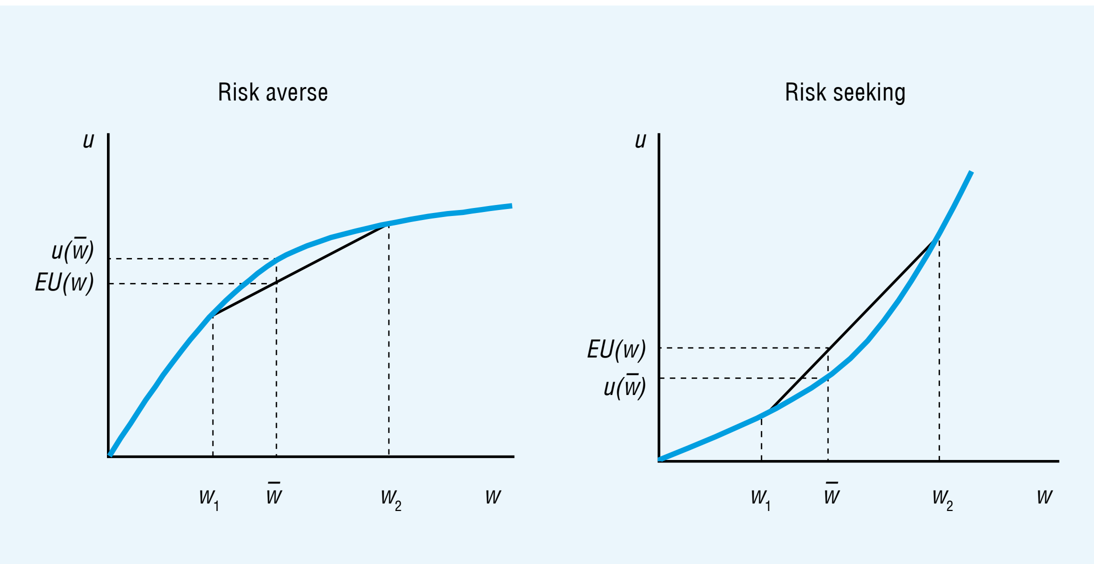
$$A(w)=-\frac{u''(w)}{u'(w)}$$

If the local risk aversion indicator of investor X, $A(w)$, is greater for every w than that of investor Y, then investor X can be said to be globally more risk averse than investor Y.

The utility function of a risk averse investor may be any concave function, and the $A(w)$ measure changes depending on the shape of the function as a result of the change of w. If, for example, the utility function is shaped like a root function $(u=\sqrt{w})$ or logarithmic function $(ln(w))$, then $A(w)$ decreases in wealth, which means that the richer we are, the less we are afraid of risk, at least in the absolute sense.[7] In the case of a quadratic utility function, for example $(u=aw-bw^2)$, however, risk aversion increases in wealth, which contradicts practical experiences.

Chart 1

THE UTILITY FUNCTIONS OF RISK AVERSE AND RISK SEEKING INVESTORS



Source: Based on Figure 11.1 of Varian (1992)

Another special case is when the utility function can be written in the following form:

$$u(w) = -e^{-aw}$$

It is easy to verify that in this case, absolute risk aversion *A(w)* is constant and is equal to parameter *a* (CARA – *constant absolute risk aversion)*. Moreover, if the wealth is of normal distribution, then

$$Eu(w) = -e^{-r(\bar{w} - \frac{A}{2}\sigma_w^2)}$$

i.e. expected utility increases in

$$\bar{w} - \frac{A}{2}\sigma_w^2 ,$$

in other words, using a monotonic transformation, we can transition from the wealth utility function to a utility function interpreted in returns, in the formula of which, with expected return ($\bar{r}$) and its variance (σ_r^2) the *A* absolute risk aversion measure continues to feature:

$$U(\bar{r}, \sigma_w^2) = \bar{r} - \frac{A}{2}\sigma_r^2$$

This utility function is the starting point for the Markowitz portfolio theory and the CAPM based on it.[8] For modelling, other risk rates may also be used in the utility function, and risk rejection takes on new meaning as a function thereof.[9]

It should be observed, therefore, that the standard risk aversion indicator *(A)* used in textbooks[10] is linked firstly to the existence of the utility function, and secondly to a very special form of this function and, furthermore, only makes sense with the normality of returns and specifically measures absolute risk aversion (calculated as an amount of money), which incidentally, in this special case, is wholly independent of the investor's current wealth situation.

The empirical experiments presented in the next section do not actually relate to the measurement of this coefficient *A*, but go deeper and ultimately question the existence of the utility function.

RISK APPETITE IN PROSPECT THEORY

Kahneman and *Tversky* conducted extensive psychological experimental research in order to map out the actual risk attitude of people. They summed up their results in their prospect theory (Kahneman and Tversky, 1979; 1992). As part of behavioural studies that have since come into scientific focus, the risk appetite of individuals and groups were examined in a number of other dimensions. We will sum up these results in the sections below.

On the trail of the utility function

The so-called Allais Paradox had significant impact on the research conducted by Kahneman and Tversky, and the paradox is presented in the former's book (Kahneman, 2011), albeit he uses an example slightly different from that of Allais. Consider the following problem-pairs:

❶ Which of the two options below would you choose?

A) 61% chance to win USD 520,000

B) 63% chance to win USD 500,000

❷ Which of the two options below would you choose?

C) 98% chance to win USD 520,000

D) 100% chance to win USD 500,000

According to experimental research, most people first choose A, then D of the options. With this, however, they commit a logical error that calls into doubt the existence of the utility function, and thus the canonical model of rational choice as well. Let's assume initially that the investor prefers option A to option *B*. In this case, according to the vNM utility function:

$$0{,}61 \times u(520) > 0{,}63 \times u(500)$$

On the other hand, in the case of a

monotonically increasing utility function, it is trivial that:

$$0{,}37 \times u(520) \geq 0{,}37 \times u(500)$$

If we add up the left and right side of the above two inequalities, then the rules of formal logic would dictate that the following be true:

$$0{,}98 \times u(520) > 1 \times u(500)$$

in other words, option C must be more valuable than option D, regardless of whether the given investor is risk averse or risk seeking. If someone were to choose options A and D in succession, this decision cannot be characterised based on the principle of expected utility, in other words, there is no vNM utility function that would correspond to this decision pair, i.e. the given individual's preference ordering does not even have the simplest good features, the decision is not consistent and as such is not rational.

In Hungarian literature, there is a misleading and increasingly widespread misconception concerning the Allais Paradox. A number of authors (e.g. Hámori, 2003; Molnár, 2006) argue that the problem with the A–D choice is that the investor is not maximising expected return, in other words, is not clearly opting for A–C, *see Table 1*.

This, however, is not a sound explanation as we clearly do not expect a rational decision maker to decide based on expected value, but on the basis of expected utility. A rational risk averse investor could safely choose options B–C or B–D, namely the options with the lowest expected value, and still avoid contradicting the principle of expected utility. But after option A, if he wants to make a rational decision, he cannot select option D due to the logic presented above.

Kahneman and Tversky also measured (Kahneman, 2011) the average subjective decision weights that experiment subjects use instead of the various objective probabilities when making risky choices, *see Table 2*.

Experiments, therefore, show that typically we are unable to handle very low and very high probabilities well, and are prone to pay too much for possibility and certainty. Based on this, the authors defined two behavioural features, which are as follows:

- *Certainty effect:* A 2 per cent improvement from 98 to 100 per cent seems more valuable than a 2 per cent improvement from 61 to 63 per cent. Even though as far as expected utility is concerned they should be worth the same. Yet, for some inexplicable reason, we pay too much to ensure that our gains change from almost certain to absolutely certain.
- *Possibility effect:* We are similarly prone to overpay to have the probability of winning increase from 0 to a very low level, i.e. we also overvalue the change when we shift from the impossible to the possible.

When these same effects are realised not just under laboratory circumstances but also

Table 1

THE EXPECTED VALUE OF RISKY PAYMENTS IN THE ALLAIS PARADOX

Payments	Expected value
A	317.2
B	315
C	509.6
D	500

Source: authors based on Kahneman (2011)

Table 2

OBJECTIVE AND SUBJECTIVE PROBABILITIES (%)

Objektive probabilitiy	0	1	2	5	10	20	50	80	90	95	98	99	100
Subjektive probability	0	5.5	8.1	13.2	18.6	26.1	42.1	60.1	71.2	79.3	87.1	92.1	100

Source: Kahneman, 2011

in actual decisions, then both insurance (certainty effect) and gambling (possibility effect) are particularly good business – from the service provider's perspective of course and not the customer's.

According to prospect theory (Kahneman and Tversky, 1979; 1992), people are not interested in the absolute level of their wealth as utility theory assumes (most of us have no idea about our current wealth). Our satisfaction is much more determined by our most recent gains and losses. If, for instance, we win HUF 10 million and lose it in the next step, we will most likely be much unhappier than if we had won nothing, even though our wealth has not changed. We have also seen that when making decisions, we are prone to using our own subjective decision weights. This outlines a fourfold pattern of risk attitudes .

As *Table 3* shows: depending on whether we are talking about gains or losses, or whether probabilities are very low or very high, we relate to risks very differently depending on the given situation.[11] In the case of large expected gains or low expected loss, we tend to be risk averse, and this is completely in line with traditional utility theory. It is also a well-known phenomenon that in the hope of very low probability gains, greed may take over from time to time and we may become risk-seeking; however, for a long time this was considered to be a marginal phenomenon that has no impact on investment decisions. But the real surprise for both researchers and the professional public came when it was found that when we are in a clearly losing situation, in desperation we are prone to taking even more risks only to have some slight hope of, by some miracle, getting away with it. This is the reason why while the shape of the gains function is concave, the loss function is convex, *see Chart 2*.

It should be noted that the real novelty here is not the fact that the results are not compatible with the general concavity of the utility function, i.e. investor risk aversion, but that they are not compatible with any wealth utility function.

Prospect theory, i.e. the value function, cannot be used to base a general portfolio theory or equilibrium pricing model on because we cannot be certain what the origin shown in the above chart corresponds to. This may be the investor's current wealth, but it may be a personal expectation which, as shown by experiments, develops and changes over time in a completely subjective and haphazard fashion (e.g. someone at one time said a round number or this is how much the neighbour won last time, etc.).

Socio-demographic-cognitive factors determining risk-taking

There has been extensive research on how people's risk propensity is related to their socio-demographic-cognitive characteristics.

The results are extremely diverse but in a simplified form, they can be summarised as follows (Varga and Ulbert, 2005):

- men are more risk-taking than women,

Table 3

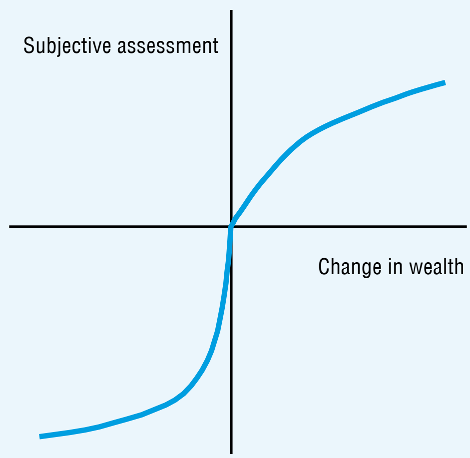
FOURFOLD RISK ATTITUDE BASED ON PROSPECT THEORY

	GAINS	LOSSES
HIGH PROBABILITY Certainty effect	risk aversion (fear of disappointment)	risk seeking (avoiding to admit loss at any cost)
LOW PROBABILITY Possibility effect	risk seeking (greed)	risk aversion (fear of greater loss)

Source: Kahneman (2011)

Chart 2

VALUE FUNCTION ACCORDING TO UTILITY THEORY



Source: Kahneman and Tversky (1979)

- young people are more risk-taking than the elderly,
- high-income people are more risk-taking than low-income individuals,
- highly educated people are more risk-taking than individuals with a low level of or no education.

These research results may be compatible with both utility theory and prospect theory, as they link risk propensity with relatively stable characteristics.

Similarly, *Frederick* (2005) has also shown that decision makers with higher cognitive capabilities are usually more risk-taking than those with lower cognitive capabilities (based on IQ and CRT test results).[12] Frederick (2005), however, did not stop here and went on to conduct more differentiated research based on the prospect theory. Firstly, he found that as far as gains were concerned, people with higher cognitive capabilities were clearly more risk-taking, and this was especially true for men. The situation in a loss-making position, however, was just the opposite, and this time around it was subjects with lower CRT scores who risked more. *Sousa* (2010), however, called these results into doubt on the grounds that increased risk-taking in the higher CRT range is the result of a better understanding of incentives and not behavioural effects. If we filter out this incentive effect, no significant risk-taking difference is observed in the dimension of cognitive capabilities, see Sousa (2010).

Other factors that determine risk-taking

However, risk-taking does not just depend on the general characteristics of experiment subjects, but also on their current physical, mental and psychological state.[13] Below is a non-exhaustive list of such effects.

▸Decision fatigue: If we are tired, we automatically become more averse to risk. Making multiple decisions depletes the self, a fact also indicated by a drop in blood-sugar levels. Recharging can fundamentally be accomplished through rest and eating, resulting in the return of the willingness to take risks (Baumeister and Tierney, 2011).

▸Social loaf: People tend to take more risks when in groups than they do alone. The main reason for this is most likely that in case of failure, blame can be shifted to the others (Dobelli, 2013).

▸Affect heuristic: If we like something or happen to be in a good mood, we perceive risk to be lower and gains to be greater than they actually are. *Hirschleifer* and *Shumway* (2003) for example examined the relationship between the daily returns of 26 stocks and morning sunshine, and found the relationship to be clearly positive.

▸Gender impulses: As part of the experiment, they showed photographs of beautiful women, and as a result participating male subjects became perceptibly more risk-taking. This, however, did not work with photographs of less pretty women or the switching of genders (Baumeister and Tierney, 2012).

▸Limelight effect: People are far more risk-taking in full anonymity than in the limelight. This calls for special attention during the planning of laboratory experiments and the interpretation of results as in this respect, the laboratory creates a secure, intimate situation which increases participant courage. In contrast, when the researchers asked for presentations before an audience or made video recordings, participants became considerably more cautious (Baltussen, van dem Assem, van Dolder, 2014). On a related note, other researchers have already pointed out that for example, as a result of the transition to online trading, investors have become more risk seeking (Barber and Odean, 2001).

▸Easy come, easy go effect *(house money effect)*: *Thaler* and *Johnson* (1990) have shown that we treat money completely differently depending on whether it was easily gained or hard to acquire. If we have won, found or inherited the money, we tend to be more easy-going about spending and risking it than we would be if we had earned it with hard work. As a result, lottery winners, for instance, usually find themselves worse off financially in a space of a few years than they were prior to winning.

▸Minsky effect: Success increases risk propensity, i.e. risk appetite increases as a consequence of successive gains (path dependency) (Minsky, 1992).

These effects are contrasting with utility theory because they question the existence of a risk-taking disposition that is stable and consistent in time and is characteristic of individuals.

ASSESSMENT OF RISK APPETITE IN PRACTICE

With respect to practical research, by risk appetite we mean the extent to which an investor is willing to take risks in a given situation, and what compensation he expects for the risk taken. Risk appetite clearly has an effect on the expected return of risky assets. If the risk appetite of market players drops, expected return increases and asset prices drop (Misina, 2003; Gai and Vause, 2005). *Dungey, Gonzalez-Hermosillo, Fry et al.* (2003) have empirically proven that the changes in the risk appetite of investors in developed markets are clearly linked to the changes of the bond return premiums of emerging markets.

During investment advising or corporate consultation, becoming familiar with the given investor's or company's risk appetite is essential for portfolio optimisation or to determine strategy and to break down this strategy into elements.[14,15] The significance of this has also been recognised by regulatory authorities. The MiFID Directive (Market in Financial Instruments Directive 2004/39/EC – European Parliament and European Council 2004) entered into force in the European Union on 1 November 2007, mandating that investment service providers assess customer risk appetite in order to be able to offer a suitable investment portfolio to all (Kaufmann, Weber, Haisley, 2013).

It is a great dilemma, however, how advisors should relate to investors' or companies' irrational intentions: should they attempt to curb it and smuggle back consistent, utility function-based decision-making; or should they become familiar with heuristics and allow them to prevail, on the grounds that for some reason, they are what makes the customer happy. Should they educate or simply serve their customers?

This section reviews the methods most widely used in practice, developed to identify risk appetite and used specifically to estimate the risk appetites of private individuals.

Based on *Grable* and *Lytton* (1999), the methods serving to assess risk appetite may be classified into five main categories, and this is also what we follow when discussing these: choice dilemma, utility theory, objective measures, heuristic judgements and subjective assessment.

Choice dilemma was a popular procedure up until the seventies. Of the related research projects, the research conducted by *Wallach* and *Kogan* (1959) focusing on the differences of decision-making processes between sexes is of note. The method placed experiment subjects into 12 different decision-making situations, where they were asked to compare risky payments (prospects) as presented earlier. One of the prospects was always riskier than the other, however, gains were also greater in the event of success. Participants were then asked with respect to all 12 decisions on how great the probability *(p)* of winning must be for the riskier alternative to make it worth selecting for them. They were also asked how certain they were of their selection on a scale of 1 to 5 (certainty factor). They then calculated the weighted arithmetic mean of p-values by using uncertainty factors as weights (Brim, 1955). Their assumption was that the greater this indicator, the greater the risk rejection. The method was criticised on several fronts. On the one hand, it seems doubtful that a concept as complex as risk propensity can be condensed into a single measure (Grable and Lytton, 1999). On the other hand, as several researchers pointed out, the application of the Brim-index cannot be entirely accepted either, because there is no close relation between risk appetite and the certainty factor (Stoner, 1968; Teger and Pruitt, 1967; Bell and Jamieson, 1970). According to another criticism, if such a relationship does indeed exist, it certainly isn't linear (Stroebe and Fraser, 1971).

The method relying on utility theory, based on the measurement of the risk aversion indicator (A) in the spirit of the Markowitz model, as presented in the first section, was highly popular for quite some time. In light of the results of behavioural finance, however, it drew considerable criticism, the most lenient of which was that in reality risk aversion is not constant, but rather a function of several circumstances, including wealth. A much greater problem though is something that prospect theory draws attention to, namely that in loss-making positions, the majority of people suddenly become risk-takers. If we choose to disregard this, we can certainly never understand the customer's true intentions (Shefrin and Statman, 1993). According to *Weber, Blais, Betz* (2002), the primary weakness of this particular method is that it fails to take into account the fact that we make different decisions in different life situations. For example, the risk appetite of a company manager is different when compiling his own portfolio than when making decisions for the company. *Kaufmann, Weber* and *Haisley* (2013) recommend the expansion of the method so that investors make decisions in line with actual utility, and avoid such pitfalls as the possibility effect or the certainty effect. In their view, a complex 'risk tool' would be required, which would not just include the numerical presentation of the risks of the various assets and portfolios, but would also have a related informative diagram, and the advisor would set up situations where investors could gain experience and learn. The researchers found that when the three methods (numerical presentation, diagram, experience) were applied together, participants were not afraid to take on substantially greater risk, and were also more consistent in their decisions.

The use of objective measures was first proposed by *Sung* and *Hanna* (1996) to measure risk propensity. In essence, under the method the relationship is determined between certain specific characteristics of individuals (age, family status, income, wealth, etc.) and their risk propensity, based on which a general model is developed that can be easily and swiftly applied in practice. By rethinking this methodology, *Hanna* and *Chen* (1997) dealt with determining the optimal portfolio for various types of investors. Their objective measures included, amongst others, the investment time horizon (1 year, 5 years, 20 years), as well as the ratio of financial assets of a single household to its entire wealth. According to *Schooley* and *Worden* (1996), objective measures provide great assistance in determining an individual's risk propensity, but we must be aware that the utility theory is behind this particular method, namely the assumption that people fundamentally want to make rational decisions. The method of objective measures was developed further by *Corter* and *Chen* (2006), who proposed a new questionnaire called Risk Tolerance Questionnaire (RTQ). They demonstrated that the questionnaire's results correlate closely with various risk rates, but not at all with an indicator capturing an emotional, subjective dimension. This led them to conclude that using a general risk appetite indicator that measures only investment risk, it is impossible to describe an individual's true risk propensity, and thus the indicator 'only' helps in driving investors towards decision making that is rational and free from subjective effects.

The heuristics method is mostly based on the socio-demographic-cognitive factors (gender, age, academic qualifications, etc.) listed in the foregoing. Extensive research was conducted in this field as well, however, there is no consensus as to which are the precise socio-demographic-cognitive factors that have the greatest explanatory power (Hallahan, Faff and McKenzie, 2003). The heuristics method does not aim to map out the imaginary utility function, but to get to know the given person, and as such, allows – as shown by its name – frequently observed heuristics to be employed. They do certainly go beyond the method of objective measures in that they also include subjective explanatory variables in the model (MacCrimmon and Wehrung, 1990; Hallahan, Faff and McKenzie, 2003).

MacCrimmon and *Wehrung* (1986) proposed a so-called subjective method that combines the various approaches. As part of the method, participants are presented with various multi-dimensional financial scenarios and situations using questionnaires and experiments. According to the researchers, the method allows the in-depth exploration of the customer's personal relationship to, for instance, bond and stock investments or the real estate market. One of the most frequently used such multi-dimensional questionnaires is the Survey of Consumer Finance (SCF), which has been conducted every three years since 1983 with the financing of the Federal Reserve Board on a sample representing the entire US population (Yao, Hanna and Lindamood, 2004). The significance of the questionnaire is well reflected by the fact that its results are considered to be a benchmark when assessing the effectiveness on other self-developed questionnaires. *Grable* and *Lytton* (1999) also created a multi-dimensional questionnaire, originally made up of 20 questions, but later reduced to 13 using factor analysis. With the help of the questionnaire, they attempted to reveal respondents' relationship to risk along the following dimensions:

❶ choice between certain and uncertain outcomes;

❷ risk-taking in general;

❸ choice between certain gain and certain loss;

❹ risk-taking based on experience and knowledge;

❺ risk-taking to reach a certain level of comfort;

❻ speculation;

❼ prospect theory; and

❽ investment risk.

The responses to the questions are given points, which are then added up. In this particular system, the higher a given person's score, the greater their risk propensity. Later on, comparing Grable and Lytton's (1999) 13-question questionnaire with the SCF (Survey of Consumer Finance) risk propensity index, *Gilliam et al.* (2010) found the former to have greater explanatory power.

Apparently, therefore, these so-called subjective multi-dimensional systems attempt to show a wide variety of aspects simultaneously; as a result, it is unclear how they actually relate to utility theory or prospect theory. It seems that in the spirit of 'compromise', they have created a confusing mixture of multiple approaches, which still stands the test of practice in many respects.

SUMMARY

In recent decades, there has been extensive research aimed at exploring how various individuals and groups relate to risk. Emerging from this research, seem to be a few stable phenomena that contradict traditional utility theory. One example is the fourfold risk model described by Kahneman and Tversky. Added to this are the correlations found between socio-demographic-cognitive characteristics and risk appetite, which are difficult to explain on a rational basis. Finally, we have also seen that a number of emotional elements also influence risk-related decisions, the effect of which is completely haphazard and unpredictable.

In light of these empirical facts, advisors must decide how far to veer from traditional utility theory during the advisory process. Should they forcibly tailor a mathematically well-behaving utility function to the customer, or should they rely entirely on the customer's current mood and seek no consistency at all? The correct approach is most likely somewhere between the two extremes, in other words, the wishes and intentions of the decision maker should be mapped out as thoroughly as possible, but at the same time the investor should also be driven towards making a rational choice.

However, it is usually left to the conscience and temperament of the given advisors whether they try to mitigate the Minsky effect; whether they advise caution for customers hyped by spring sunshine; whether they invite customers to have a sugary soda before making important decisions; or they go even further and persuade shy female customers to take greater risk, or perhaps force consistent decision making or even strict risk averse behaviour.

Based on the review of practical models aimed at assessing risk appetite, we can state that the players of the advisor industry have not cleared up at all what their role is exactly, and how far they should go in serving their customers' irrational desires and heuristics. The only consensus is that risk appetite should be measured some way or another, and regulators are also in total agreement.

Notes

[1] Acknowledgements: The authors wish to thank the Hungarian Academy of Sciences for the support of its Momentum Programme (LP-004/2010), which made this research possible.

[2] The price of derivatives also depends on these preferences through the price of the base product, see Dömötör (2011).

[3] This sub-section was written on the basis of Varian (1992).

[4] Affine transforms (multiplication by constant and shifting) do not modify the vNM utility function.

[5] The various rationality concepts were addressed in depth by Jáki (2013a), who also examined their realisation empirically in a later related article (2013b).

[6] This is called absolute risk aversion, which measures how the investor reacts to a given amount of change in their wealth. By examining how a given percentage of change in their initial wealth impacts their utility, we determine relative risk aversion (RRA).

[7] Absolute risk aversion is for a root function, and for a logarithmic function. In contrast, the relative risk aversion measure (CRRA – constant relative risk aversion) is constant for these functions (always ½ and 1 respectively).

[8] The same utility function is used in portfolio selection theories with downside risks, see Walter and Kóbor (2001).

[9] On selecting the appropriate risk rate, and the correct distribution of risk within an organisation, see Csóka, Herings, Kóczy (2007) and Csóka (2003).

[10] See for instance, Bodie, Kane, Marcus (2014); Fazekas, Gáspárné, Soós (2008).

[11] Expectations of uncertainty and success in connection with EPS forecasts was examined by Jáki and Neulinger (2013).

[12] Intelligence Quotient Test and Cognitive Reflection Test

[13] The behavioural causes of systematic optimism were examined by Jáki (2013b). Her research focused on the presentation of overconfidence, overoptimism and the psychological immune system.

[14] It is also in the context of corporate risk management that the corporate utility function can be interpreted.

In such cases, the starting point is usually the notion that relative risk aversion is constant (CRRA – constant relative risk aversion), see Dömötör (2013)

[15] Homolya (2007) reviews the possible methods of determining risk tolerance in the field of banking operational risk management.

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