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HOW TO PREDICT GENDER-DIFFERENCES IN CHOICE UNDER RISK: A CASE FOR THE USE OF DECISION MODELS*

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Women are stereotyped as more risk averse than men. Empirical and experimental investigations seem to support the stereotype, yet they tackle different and often unrelated aspects. Reliable predictions on gender specific differences in risky choices are hardly possible since there is no common or consistent theoretical underpinning. To enable predictions, this paper tries to integrate gender aspects into five main models from decision theory. We can show that according to the model considered different sources for gender differences in risky choices appear relevant. This implies that the model choice has relevant implications for predictions of gender differences in risky choice. (JEL D81, J7)

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1. Introduction

It is a well-known stereotype that when confronted with risky decision situations, women choose low-risk alternatives whereas men choose alternatives with higher risks[1], leading to the common assertion that women are more risk averse than men. This stereotype has important implications because it can result in statistical discrimination against women. For example, if women are thought to be more risk averse than men in financial markets, brokers will offer women portfolios that are characterised by low risks and low long-term returns. Men on the other hand will be offered portfolios with higher risks and higher long-term returns on average. As a result, the level of long-term returns for women will remain relatively low irrespective of their individual risk attitude because their income and wealth position is lower on average compared to men. The market implication is that women will be caught in a low return investment trap.

Another example occurs when employers assume that women are more risk averse than men, and also assume that top managers are generally more risk seeking. In this case, statistical discrimination may arise in the sense that women are not promoted to top management positions even if their individual level of risk aversion is low. This is one explanation of the glass-ceiling phenomenon. The result is a sub-optimal allocation of human capital resources.

Given the potential for market discrimination and the consequences arising from stereotyping women as more risk averse than men, it is important to establish the strength of empirical support for this stereotype. However, the overall picture derived from the existing evidence is unclear because different empirical and experimental studies deliver evidence on

[1] In this paper only choices under risk are considered. For sake of simplicity choice situations under ambiguity are not dealt with.

a multitude of different and often unrelated aspects of the gender issue.

The existing evidence cannot be used to test the gender risk stereotype or to make reliable predictions on the choice behavior of men and women with respect to risky decisions. Such predictions, however, would be necessary in order to assess ex-ante the implications of measures in fields where risks are involved, such as the privatization of public pension systems or marketing strategies for financial products or for products with potential environmental or health damages.

The problems with the evidence arise mainly from the fact that most relevant empirical and experimental studies are undertaken without an explicit theoretical framework or formalized model. To produce comparable evidence and to explain apparent contradictions in the evidence base, requires the use of formal decision models based on explicit theory.

This paper aims to show how gender might be integrated with existing formalized decision models. Several main models from economic and psychological decision theory will be considered. The aim is to integrate gender in such a way as to allow comparison between different models on a theoretical level as well as with respect to evidence produced. This will create a basis for consistent and systematic evaluation of existing evidence. It will also create the basis for generating consistent empirical testing of model parameters for use in policy and business decisions where consideration of gender differences in choice behavior under risk is important.

2. Empirical Evidence on Gender Differences

The evidence on gender differences in decision choice can be found in the psychological and economic literature on risky decisions, especially on attitudes toward risk,

on choice outcomes under risk, and on individual factors affecting decisions under risk. The following discussion critically examines the key trends and contradictions in the empirical literature and assesses the source of the empirical problems discussed earlier in more detail.

One of the main trends in the literature is the stereotypical view that women avoid risky situations more than men. A review of the evidence on gender differences in attitudes to risk shows as most consistent result that women avoid risk more strongly than men in experiments using risky gambles (Levin et al., 1988; Johnson and Powell, 1994; Powell and Ansic, 1997; Powell and Ansic, 1999), but also in more general decision tasks (Barsky et al., 1997; Jianakoplos et al., 1998; Grossmann and Eckel, 2000). However, contradictory evidence also exists (Johnson and Powell, 1994; Schubert et al., 1999) to shed doubt on the findings. One explanation of the contradictions lies in the use of inconsistent terminology (Schoemaker, 1993) and the lack of theoretical modelling in most studies. For example, in behavioural studies in business and finance (e.g. Stinerock et al., 1991), the measure of risk avoidance is usually a measure of the outcome of risk behaviour. In experimental studies, however, risk avoidance is usually measured by either the stated risk premium or willingness to pay. The former is a measure of the outcome of the decision whereas the latter is a measure of a component in the decision process. Another explanation is that contradictory outcomes stem from other factors in the decision process which moderate the effect of risk attitude, such as individual characteristics and the framing of the decision task.

The vast majority of the empirical literature on gender differences affecting decisions under risk focuses on individual characteristics. Gender differences in domain familiarity and experience have been shown to affect decisions under risk (Levin et al., 1988; Johnson and Powell, 1994; Schubert et al., 1999), as have social factors such as social roles (Voelz, 1985; Radecki and Jaccard, 1996). Gender differences in personality and emotional variables are also identified as important in some contexts but not in others (Loewenstein et.

al., 1999). Such exogenous factors affect the decision process in different ways and may explain some contradictory evidence. For example, Johnson and Powell show that gender differences in risky choice behaviour in the general population disappear when both male and female subjects are familiar with the task (Johnson and Powell, 1994).

The most dominant finding on individual characteristics is that men are more confident than women in decision making under risk (Estes and Hosseini, 1988; Stinerock et al., 1991; Zinkhan and Karnade, 1991; Beyer and Bowden, 1997), although this has been shown to depend on the degree of ambiguity in the decision task (Powell and Ansic, 1999). Men are also found to be more overconfident in some studies (Lundeberg et al., 1994; Barber and Odean, 2000), and this has been linked to gender differences in self-serving attribution bias (Meehan and Overton, 1986; Gervais and Odean, 2001), and motivation (Schneider and Lopes, 1986; Arch, 1993). Whilst the evidence is quite consistent on this factor, gender differences in confidence will only be associated with gender differences in risk attitude if all other factors in the decision process reinforce the effect of confidence.

The interaction of such effects is complicated by the existence of gender differences in many of the factors affecting the decision process. For example, gender differences have been found in the notion of risk used in the decision process. These are generally attributed to the extent to which men focus on the probability component leading to low risk definition and women focus on the future consequences, leading to high risk definition (Vlek and Stallen, 1981; von Winterfeldt et al., 1981; Hansson, 1989; Dorttz-Sjöberg, 1991; Yates and Stone, 1992). Gender differences in framing in terms of gains and losses (Levin et al., 1988) and framing in terms of the decision context (Bromiley and Curley, 1992; Schubert et al., 1999) are also important factors. For example, money represents a specific form of personal property, and gender differences arise in attitudes to property (Furnham, 1984; Dittmar, 1992; Prince, 1993). Women appear more fearful of losses in general, and property loss in

particular. These factors may account for some gender differences in perceived options for choice.

Finally, the evidence of gender differences in risk evaluation is primarily based on gender differences in risk perception. Whilst there is little evidence of statistical differences in overall risk perception, many studies suggest women perceive higher risks than men in relation to specific activities such as smoking and air travel (Slovic, 1992; Flynn et al, 1994; Jungermann, et al. 1996; Schubert, 1997). Women are also found to perceive higher risks than men in certain domains such as environmental risks and nuclear power risks (Drottz-Sjöberg, 1991; Brun, 1994; Greenberg and Schneider, 1995). These differences have been linked to the strength of factors such as dread, knowledge and conspicuousness (Cutter et al., 1992; Schubert, 1997), all of which may be moderated or reinforced by gender differences in individual factors and the factors in the decision process.

The evidence reviewed above clearly indicates the need for a more model driven approach to empirical testing. The existing evidence is contradictory not because one study is right and another wrong, but because each study focuses on only a small fragment of the decision process. More reliable predictive models are required in which the apparent contradictions on gender can be assessed and potentially explained. The most appropriate models for an initial exploration of gender issues are the main theoretical models of individual decision choice under risk.

3. Modelling Individuals' Choice Under Risk

There are currently five main theoretical models of decision making under risk. They are Expected Utility (EU), Rank Dependent Expected Utility (RDEU), Prospect Theory (PT) and Security Potential/Aspiration theory (SP/A), and Risk/Return models

(R/R). Whilst all five have advantages and disadvantages in the analysis of decision behaviour, none of them has been used to address the gender difference issue. Our aim is to examine the extent to which gender differences can be introduced and assessed within these models.

The five main models have some similarities, but also have substantive differences in use of terminology, definition of risk and explanations of how risk enters the decision process. To avoid the problems of confusing terminology and to aid the interpretation of how gender can be introduced into these models, we first categorize the key features of these models.

The five models we consider are all models of individual choice, with inputs from two sources. On the one hand, the individual is faced with a decision information including information on probability and outcomes. On the other hand, each individual brings to the decision process a set of characteristics such as prior experience and personality. Both the information set and the individual characteristics are exogenous in the models and are fixed. As mentioned earlier, individual characteristics play an important role in the empirical evidence. These exogenous individual factors are shown as box A in Figure 1 below. Box A would include for example, Schoemaker's intrinsic risk aversion (Schoemaker, 1993), individual levels of confidence, and personality and emotional factors that form the basis of so much of existing evidence.

Boxes B and C in Figure 1 illustrate the key elements of the process of decision choice. An individual firstly attempts to structure the decision. Structuring includes defining concepts such as risk and outcomes, sorting information and determining the complexity of the decision. The individual then assesses all the factors including risk, i.e., the individual gives a measurable value to the definitions and determines the value of the various options.

If, for example, someone has defined risk as simple expected utility in the structure stage, then the person must assign a mathematical value to the probabilities and outcomes, and determine the expected value in the assessment stage.

Any decision process implies an integration of the boxes A to C to produce a final choice outcome. This may involve a number of moderating influences between boxes A, B, and C. Let us now consider in greater detail the role and importance of boxes A to C as key elements of decision-making processes where risk is involved.

Figure1:

Besides clarifying the notion of risk, *structuring* also means defining a set of perceived options and criteria for evaluating choice (Schoemaker, 1993). Perceived options represent the relevant choice alternatives to the individual, and the criteria represent the goals pursued by the individual. In terms of decision models, structuring involves defining a function to determine the value of each option. Structuring also means choosing a decision rule such as maximisation of the options' value.

Individuals will process given decision information in different ways and display different biases depending on their *individual characteristics* and on the quantity and quality of the decision information.[2] The structuring process may for instance be subject to biases such as the familiar problems of anchoring, especially of reference point determination, and of availability. These too may display distinct gender differences. For example, women may have a tendency to anchor on the status quo more than men if they are motivated more by security than reward (Arch, 1993).

In the *assessment* phase, individuals must determine the value of options by placing estimates for operationalized variables on outcomes and likelihoods. This is typically represented as a mathematical function in a choice model. As a rule, the outcome values are influenced by individual characteristics and by the structuring process. The assessment of likelihoods is influenced by beliefs, risk perceptions and the impact of events on the desirability of prospects (Kahneman and Tversky, 1979). These factors are also subject to biases like representativeness, and the isolation and certainty effects (McFadden, 1999). Gender differences may arise in all assessment biases. For example, women may perceive higher risks in a given situation if they are more prone to the representativeness bias.

A predictive decision process model indicates the process by which individual characteristics interact with the structuring process, given the type of decision information,

and also the way in which these factors interact with the assessment process. Each of the five main models mentioned before approaches this interaction in a different way and hence the degree to which gender differences can be explored differs between the models. However, relevant hypotheses about gender differences relate to the whole process.

[2] Different possible biases, or cognitive anomalies, have been summarized in a comprehensive way by McFadden (1999).

Therefore, comparing different models on the basis of the aforementioned key features delivers a better understanding of how gender differences in the decision process mayinteract to determine decision outcomes under risk.

4. Five Different Models for Decision Making under Risk

4.1 Expected Utility Model

Expected Utility theory (EU) would be an obvious model to start the analysis of decision making under risk. EU is still the main model in economics.

In the EU model, in the structuring phase the value V of an option a_j (j = 1, 2, ..., J) is expressed by the option's expected utility:

(1) $$V(a_j) = \sum_{1}^{N} p_i \, u(x_i),$$

Hereby, p_i is the probability of an outcome x_i (i = 1, ..., N) which might result from the application of the corresponding alternative, with $\sum p_i = 1$. $u(x_i)$ is the utility of outcome x_i. The utility function u represents the individuals' preferences over sure outcomes x_i.

In EU theory, equation (1) is typically derived under the assumption of three axioms, i.e. the ordering axiom, the continuity axiom, and the independence axiom. Within EU theory individuals maximize the value of V over all relevant alternatives, given individual constraints such as financial budgets. In the assessment phase, utilities of the outcomes are rated and the above mentioned value function is maximised.

In the EU model financial wealth is an exogenous variable. Additionally, it is assumed that probabilities are perceived in an objective way so that there is no difference between a belief and the objective probability of an alternative. Probability and utility

functions are also assumed independent. As a result, in the EU model, gender differences in decision behaviour can only result from differences in the utility functions.

In the EU framework two well-known aspects of risk are discussed: The *Arrow-Pratt* measure of risk aversion (Arrow, 1963; Pratt, 1964) and the notion of increasing risk (Rothschild and Stiglitz, 1970). Risk aversion is measured by the curvature of the utility function. The more concave the utility function, the more risk averse is the individual. Therefore, one relevant hypothesis would be that there are gender differences in the concavity of the utility function.

The notion of an increase in risk refers to the economic consequences of adding a zero mean noise to a random variable. A risk averter for whom the utility function is concave always prefers the random variable without noise. So gender differences in increasing risk may exist in cases of varying utility functions.

Current theory suggests that risk aversion in terms of the curvature of the utility function, is explained solely by diminishing marginal utility to wealth (Wakker, 1994; Rabin, 2000)[3]. In this case, gender differences in utility functions stem from the fact that men and women react differently to changes in wealth.

Rabin shows further that for decisions with modest stakes (like decisions in experiments) EU has an important inconsistency. EU implies that individuals are risk neutral in decisions with modest stakes (Rabin, 2000). Observing individuals in experiments being risk averse may therefore be an argument against EU. Thus, it seems appropriate to investigate whether other models for decision making under risk are more suitable for an

[3] However, there is an alternative view that it is impossible to determine whether a difference in curvature is related to differences in diminishing marginal return to wealth or to differences in other determinants of risk attitude (Chateauneuf and Cohen, 1994).

explanation of observable gender differences in risky choice behaviour.

4.2. Rank Dependent Expected Utility Model

Rank Dependent Expected Utility theory (RDEU) was first introduced by Quiggin to provide a decision model with more predictive power than EU and to address the well known paradoxes identified by Allais (Allais, 1953; Quiggin, 1982). RDEU attaches values V to alternatives a_j which are quite similar to the values from equation (1). However, it gives non-linear weights to probabilities by using decumulative probability functions. These decision weights π_i represent a ranking in the perceived importance of the outcomes x_i and they typically differ from objective probabilities p_i (Diecidue and Wakker, 1999).

As in EU, alternatives are more preferred with higher values of V, as the value V is maximized over all relevant alternatives, taking into account individual constraints. Utility functions and the decision weights are assumed to be independent. The axiomatic requirements for the value function are less demanding than in EU due to the comonotonic independence axiom. The general functional form of an alternative's value is:

(2a) $$V(a_j) = \sum_{i=1}^{N} \pi_i u(x_i)$$

with

(2b) $$\pi_i = w(\sum_{h=1}^{i} p_h) - w(\sum_{h=1}^{i-1} p_h)$$

where $w(.)$, the weighting function, is a strictly increasing function that maps the interval [0,1] on itself with $w(0)=0$ and $w(1)=1$.

In RDEU again two aspects of risk are important: on the one hand the shape of the weighting function reflecting importance ranking of potential outcomes, and on the other hand, as before, the concavity of the utility function possibly representing diminishing marginal return to wealth (Wakker, 1994). Due to the weighting function it is now possible

that an individual is risk seeking in the EU sense, and is at the same time risk averse in the sense that he or she devalues the probabilities of positive outcomes the higher the outcome is. Such distortion is represented by a convex weighting function (Chateauneuf and Cohen, 1994).

The most common functional form for the probability weighting function is the one first introduced by (Lattimore, Baker and Witte, 1992):

(3) $$w(p) = \delta p^{\gamma} \; / \left[\delta p^{\gamma} + (1-p)^{\gamma} \right]$$

where *p* stands for the sums of probabilities as given in (2b).

In addition to differences in the utility functions, in RDEU, gender differences in risky choice behaviour can occur due to differences in either the curvature (expressed by δ) or the elevation (γ) of the probability weighting function. According to Gonzales and Wu the *curvature* is related to the psychological concept of *discriminability* (Gonzales and Wu, 1999). Discriminability means diminishing sensitivity in the sense that individuals' sensitivity towards changes in probability is decreasing with increasing probability (Tversky and Kahneman, 1992). In other words: individuals become less sensitive to changes in probability when they move away from a reference point. Sensitivity therefore implies an inverse S-shape of the weighting function. The *elevation* of the probability weighting function reflects the judgement of *attractiveness* of an alternative to an individual. It represents the absolute level of *w(p)* and is independent of the curvature. An individual judges an alternative more attractive, if and only if he or she assigns more weight to all probabilities[4].

[4] A different interpretation of decision weights can be found in Loebman (1994). There, the decision weights are interpreted in terms of under- and overestimation of probabilities, specified as pessimism and optimism. This interpretation is a behavioural property whereas the above interpretation is about cognitive biases.

It turns out that RDEU offers possibilities to explain gender differences in observable choice behaviour which are more satisfactory than the possibilities within EU. However, the psychological underpinning of RDEU is still relatively weak. Decision models presented in the following sections put more emphasis on the psychological background of decision-making.

4.3 Prospect Theory

Prospect Theory (PT) was first proposed by Kahneman and Tversky to explain anomalies and biases in decision behaviour which could not be explained by EU (Kahneman and Tversky, 1979; McFadden, 1999). PT's innovation is that for the evaluation of alternatives two different parts of a value function are considered according to whether gains and losses from a reference point are involved. The structure of the two parts of the value function resembles the RDEU function (2a), in the sense that it includes decision weights. However, in a first step, decision weights for outcomes x_i are based only on probabilities p_i.

The decision process is central to the model and can be separated into an editing and an evaluation phase. The *editing phase* in PT is both a structuring task and an assessment task, where the individual simplifies the problem (Kahneman and Tversky, 1979) and creates a reference point with a value of zero. Outcomes are then expressed as positive or negative deviations from this point (gains and losses). The individual finally determines values in relation to the reference point for the utility and weighting functions, determining

the shape of the functions. Gender differences in risky choices might arise from differences in reference points because reference points can be affected by individual factors like expectations and decision information such as social roles (Kahneman and Tversky, 1984).

The utility function tends to be concave for gains and convex for losses, and is steeper for gains than for losses, so that the comfort of a marginal gain is outweighed by the discomfort of a similar loss. As a result, most people display loss aversion by rejecting favourable lotteries. Men and women may display varying values for identical alternatives due to differences in the steepness of the utility function. As in RDEU models, decision weights can also be influenced by subjective probabilities and other factors such as for instance dread (Tversky and Kahneman, 1981), which may give rise to gender differences.

The *evaluation phase* is an assessment activity in which an optimal alternative is the option with the maximum value, determined (as indicated in equations (2a) and (2b)), by the product of the value function and the decision weights. In PT, non-linearity in the utility and weighting functions is assumed. This means that different frames can lead to different preferences over risky options, with the potential for explaining gender differences in outcome behaviour, but with the disadvantage of violating the assumption of first-order stochastic dominance.

PT was redrafted as an explicit form of rank dependent utility model (Tversky and Kahneman, 1992) to avoid the problem of first-order stochastic dominance. As in the case of RDEU, the decision weights for outcomes x_i become dependent not only on the probability p_i of the outcome, but on the whole probability distribution. The model follows the same general functional form as shown for RDEU in equations (2a) and (2b) above, but with a separate cumulative distribution function for gains and losses. It is called Cumulative Prospect Theory (CPT).

In PT the value V of an alternative a_j can be indicated as

(4a) $$V(a_j)=\sum_{i=1}^{N_1}\pi_i^{\,L}\cdot u(x_i^L)+\sum_{i=N_1+1}^{N}\pi_i^{\,G}\cdot u(x_i^G),$$

with

(4b) $$\pi_i^L = w^L(1-\sum_{h=1}^{i-1}p_h)-w^L(1-\sum_{h=1}^{i}p_h)$$

and

(4c) $$\pi_i^G = w^G(\sum_{h=1}^{i}p_h)-w^G(\sum_{h=1}^{i-1}p_h).$$

The index L stands for losses and the index G for gains. From equation (4a), it is assumed that you have N_1 loss outcomes and $(N-N_1)$ gain outcomes. The magnitude of N_1 or $(N-N_1)$ respectively is determined by the individual's reference point.

Following Tversky and Kahneman's, the utility function $u(x_i)$ based on a reference level "zero" is given by:

(5) $$u(x_i) = \begin{cases} x_i^{\alpha} & \text{if } x_i \geq 0 \\ -\lambda\,(-x_i)^{\beta} & \text{if } x_i < 0 \end{cases}$$

The slope of the utility function $u(x_i)$ above the reference point is defined by the value of α, and by the value of β below the reference point. The value of λ defines the relative slope of the two functions above and below the reference point. $\lambda > 1$ implies that the loss section below the reference point is steeper than the gain section above the reference point, "zero", reflecting loss aversion (Tversky and Kahnemann, 1992).

Gender differences in risky behaviour may be due to differences in the utility function. The function might be more concave for gains if women are more risk averse for gains, so that the value of the parameter α is smaller for women than for men. The function might be more convex for losses if women are more risk seeking for losses, so that the value of β is also lower for women than for men. The utility function might also be steeper for

women (a higher value of $\lambda > 1$) if women place a higher value on the loss of given amount over a gain of the same amount than men.

In CPT, the weighting functions $w^L(p)$ and $w^G(p)$ have the same interpretation as the $w(p)$ function in the RDEU models. CPT generally assumes that the decumulative weighting function is inversely S-shaped for gains and S-shaped for losses. So, as before, gender differences may arise because of differences in discriminability or attractiveness. However, in CPT gender differences may also result from gender differences between the gain and loss domain.

4.4 Security Potential/Aspiration Model (SP/A)

The SP/A model was developed by Lopes as an alternative to the PT (Lopes and Oden, 1999), and differs from other models in that it is based on motivation theory. Lopes and Oden argue that the operation of psychological factors is explicit in SP/A theory, whereas it is hidden behind the single evaluation of lottery attractiveness in other theories.

In the SP/A model, the Value V of an alternative a_j is represented by a function f on the security-potential level (SP) and the aspiration level (A):

$$V(a_j) = f(SP, A) \tag{6}$$

The SP and A criteria are assumed independent, based on the psychological concepts of motivation regarding individual beliefs about the characteristics of the risky choice situation, and the goals people hope to achieve.

The *SP criterion* describes individual disposition toward risk derived from how a person normally evaluate risks. This disposition is modelled by more or less risk averse or risk seeking preferences, and is be affected by individual characteristics. Risk aversion is defined as a focus on the worst outcome, leading to a desire for security, and a tendency to

weight the worst outcomes in a lottery prospect more heavily than the best outcomes. Risk seeking is defined as a focus on the best outcome, or on the potential of alternatives, with a tendency to weight the best outcomes in a lottery such as large gains or small losses, more heavily than the worst outcomes.

The SP criterion is modelled by a decumulatively weighted value rule analogous to equation (2a). As before, decision weights π_i are explained by decumulative probability functions as shown in equation (2b). Yet, the utility function u is assumed to be linear in the outcomes x_i. Therefore:

(7a) $$SP = \sum \pi_i \, x_i$$

(7b) $$\text{with } \pi_i = w(\sum_{h=1}^{i} p_h) - w(\sum_{h=1}^{i-1} p_h)$$

Similar to CPT, the weighting function w, contained in π_i, can be different for gains and losses (Oden and Lopes, 1997). In addition, w's functional form differs from equation (3) in relying not on cognitive but only on motivational parameters:

(8) $$w(p) = vp^{q_s+1} + (1-v)[1-(1-p)^{q_p+1}]$$

where p stand for the sums of probabilities given in (7b).

The parameters q_s and q_p are thought to represent the rates at which attention to the outcomes, x_i, falls as assessment proceeds in the bottom-up or top-down direction. However, the range of feasible values for q_s and q_p is not clearly indicated. The parameter v determines the relative impact of security and potential aspects. For $v = 1$, the individual is assumed totally security minded, for $v = 0$, the individual is totally potential minded. For $0<v<1$ the individual is "cautiously hopeful" (Lopes and Oden, 1999).

The *aspiration criterion A* captures context factors relating to the decision content, reflecting the evidence from protocol data that people think of risk in terms of the

probability of not achieving a target (Schneider and Lopes, 1986; Lopes and Oden, 1999). Equation (9) shows one out of several possibilities to operationalize *A*. According to this equation, A_i indicates individuals' estimates p^e of the probability that an outcome x_i satisfies their given aspiration level α:

$$A_i = p^e (x_i \geq \alpha). \tag{9}$$

In (9), α represents the individuals' reference point, which in contrast to the CPT model, is independent of the individuals' preference function. However, equation (9) does not contain any aggregation rule yielding *A* for given A_is.

At present, the SP/A model does not specify how the *SP* and *A* criterion are combined into a single choice (Oden and Lopes, 1997). The aspiration level may reinforce the effect of the *SP* factor or moderate its impact. However, the functional form of *f* is not specified nor is it clear from literature whether *f* contains specifiable parameters, or whether all parameters of the *f* function are fixed ex-ante.

Gender differences in risky choices may arise from an SP/A model if one group is more motivated by security, the *SP* criterion, whilst the other group is motivated by returns, the *A* criterion (Arch, 1993). Theories of bio-chemical factors and evolutionary factors (Kenrik, 1994) seem to justify the assumption that women are more security driven whereas men are more motivated by returns.

Additionally, gender differences may arise from differences in the SP or *A* criterion, respectively. *SP* differences may result from differences in weighting functions, described by differences in the parameter mentioned in equation (8). In other words, differing attention to outcomes or differing security-mindedness may lead to gender differences in *w* and hence in π_i. Varying security-mindedness of men and women my be explained by observed

asymmetries between gains and losses in lottery choices. Lopes and Oden cite the most commonly observed case that people are found to avoid risks strongly for gains but are risk neutral for losses (Lopes and Oden, 1999). This pattern could explain gender differences if for instance women were more security-minded than men.

Gender differences in *A* may occur due to varying aspiration levels. Women may set a more modest aspiration level for gains than men do. In this case the SP and A factors would reinforce each other. On the other hand, women may set a higher aspiration level than men for losses, because they want to lose as little as possible (cf. section 2 of this paper), making the *SP* and *A* factors conflict. This effect may be assumed to be more prominent in contexts where women have less confidence and experience, and where the affective factors are strong.

It turns out that the SP/A model has several similarities with the CPT models. However, in contrast to these models, cognitive aspects are dominated by motivational aspects. Yet, since the characterization of the *f* function as well as the operationalization of the *A* criterion are rather fuzzy and incomplete, different interpretations are possible making precise predictions of choice behaviour impossible.

4.5 Risk/Return Models

Risk/Return models (R/R) generally postulate that individual preferences over risky options depend on the return value *RV* of the options as well as on the options' riskiness, *R*. The value *V* of a choice alternative a_j can then be calculated as:

(10) $$V(a_j) = g\,(RV, R).$$

A standard assumption concerning the *g*-function is that the first derivative of *g* with respect to *RV* is positive whereas it is negative with respect to *R*. Furthermore, it is often assumed that the second order derivatives are negative for *RV* and positive for *R*.

Normally, the return value *RV* is measured by the Expected Value *EV*. For the risk component *R*, different notions can be found.

One of the first authors to work with an R/R model was Markowitz (Markowitz, 1959). The risk notion he used was an option's *statistical variance*. This implies that in case of an objectively given return value *EV*, gender differences in observable risk behavior can only be explained by differences in the *g*-function. In other words, if *EV* and the statistical variance are used to operationalize the return value and the risk variable in equation (10), both men and women may demonstrate the same behavior towards risk if they are characterized by identical risk preference functions *g*.

Such implications had been contested by Allais who emphasized that the riskiness of a (financial) choice option should not be represented by the statistical variance of an option's possible outcomes but by a measure of the subjectively perceived risk *PR* (Allais, 1979). In this way gender differences in the structuring phase which may be partly based on gender differences in individual characteristics can account for varying risk behavior of men and women even if they display the same preference function *g*.

Within the framework of a Perceived Risk / Return model (PR/R), observable differences in men's and women's observable risk behavior can then be explained in three different ways. First, one may presume that men and women differ in the risks they perceive. From various empirical studies it is known that on average women perceive higher risks than men (Schubert, 1997).

Second, one may suppose that men and women differ in their *g* functions, resulting in gender differences in the trade-off between *EV* and *PR*. It seems plausible to assume that women have a lower preference for risk than men and that their marginal rate of substitution of *EV* by *PR* is relatively high. If the female marginal rate of substitution is higher than the male rate, choices will show a lower level of *PR* for a given level of *EV*.

The third way of explaining gender differences in behavior towards risk lies in a combination of the two effects discussed above. This combination of effects may also be relevant in cases where there are no observed differences in the behavior towards risk, because differences in *PR* and differences in *g* may cancel each other out. As a result of this combination effect, the PR/R model dominates the Markowitz model with respect to explanatory and predictive power concerning decision choice under risk (Weber and Hsee, 1993; Weber and Milliman, 1996;).

However, an important problem in the PR/R model remains the question of how to operationalize the *PR* variable. Research into the determinants of risk perception shows that the Conjoint Expected Risk (CER) model developed by Luce and Weber (Luce and Weber, 1986) is most successful in accounting for many empirical findings and assumed anomalies in risky decision-making (cf. Brachinger and Weber, 1996). The CER model constitutes an important part of an individual's structuring as well as assessment process. It explains *PR* as a combination of the probability of loss, the probability of status quo and the probability of gain as well as of the expected gain and the expected loss of a choice option.

The explanation of perceived risk offered by the CER model does not fully coincide with empirical research on risk perception. The psychometric work done by Slovic and others suggests that not only cognitive but also emotional elements play a decisive role for the perception of risk (cf. Slovic, 1992; Schubert, 1997). Variables like dread, voluntariness,

controllability, catastrophic potential, fatalities, immediacy of effects, and familiarity for instance, seem to matter.

There have been some attempts to combine the CER model with the results from psychometric studies in so-called hybrid models. A hybrid model which proves to have high explanatory power for health as well as financial contexts has been developed by Holtgrave and Weber (Holtgrave and Weber, 1993). The CER model is extended by including a worry variable, which represents (negative) affective components of risk. This model accounts for more of the variance in revealed risk perception than either pure CER models or pure psychometric models. Slovic's results suggest that the CER model could also include additional psychometric variables such as knowledge to represent scientific knowledge and individual familiarity.

Taking into account the above arguments, gender differences in the perceived riskiness of an option may be essentially due to two reasons. First, while most CER variables are objectively determined by the choice options themselves, gender differences may arise in the coefficients of these variables, i.e. in the weights of the different exogenous variables within the CER model.

Second, gender differences may arise in the psychometric components, like worry and knowledge, either through the variables themselves or through their coefficients. This means that the relative importance of cognitive and affective components of *PR* may differ between men and women.

More knowledge on the relative importance of cognitive and affective aspects would finally allow empirical testing of the signs of the *g*-function's derivatives. A positive sign for *g*'s derivative with respect to *PR* would indicate that for the individual considered risk is so attractive that an increase in *PR* need not be compensated by an increase in *EV*. In this

context, men may be more likely than women to have a positive first derivative of g with respect to PR, if a loss and even a potential loss in return value causes more psychological problems for women than men (cf. section 2).

5. How to Predict Gender Differences in Choice under Risk

At the start of this paper, we argue that establishing the extent and nature of gender differences in decision making under risk is important because actual and perceived differences affect market behaviour. Actual differences matter because they lead to differences in decision outcomes that may need to be redressed by policy action. Perceived differences matter if they lead to incorrect stereotypes and hence to sub-optimal results. In either case, policy intervention cannot be based on existing evidence, since the evidence offers a puzzling magnitude of potentially inconsistent observations. In order to predict gender differences in choice under risk in a meaningful way, we need to undertake empirical testing within formal decision process models.

In Sections 3 and 4, we show how gender differences in individual characteristics, structuring and assessment enter the decision process. In many cases, the interaction of differences may reinforce each other, leading to observable gender differences in behaviour. However, process models could also reveal how differences may compensate each other so that finally no visible gender differences in choice behaviour remain. Such compensation effects may account for some of the apparent contradictions in the existing evidence base.

We also show that the five main decision models can be used to develop testable hypotheses on the existence of gender differences. All five models deliver explanations for choices under risk and allow for predictions of men's and women's choices as well as for gender differences in choice behaviour. In a stylized form, each of the models can be

represented by a value function $V(a_j)$. For all cases, the decision principle is such that the alternative yielding the maximum V should be chosen.

The five models offer different explanations for gender differences in risky choices. Hereby, as can be seen from the second column in Table 1, the first three models (EU, RDEU, PT) and the fifth model (R/R) form two groups of general approaches for modelling choice behaviour. In the first group of models there is a clear distinction between probability aspects of risky choices and preference aspects concerning sure outcomes. Probability aspects may include objective as well as perceived aspects. In the second group however, probability aspects and sure outcome aspects are mixed. They are reflected in two variables which determine alternatives' values, one that is directed towards the perception of risks (*R* or *PR*, respectively) and another one which is directed towards (perceived) potential returns (*RV* or *EV*, respectively).

The SP/A model seems to stand between the two groups. On the one hand, it resembles the PT models as is evident from the definition of the SP criterion. On the other hand, as can be seen from equation (6), there may be similarities with the R/R models at least in the case where the parameters of the *f* function are not fixed ex-ante. In this case, an SP/A model can be perceived as a model in which the SP criterion stands for the risk aspect of alternatives whereas A represents the return aspect. Both aspects are mixed within the *f* function. However, literature on SP/A models seem to suggest that *f*'s parameters are fixed ex-ante. In this case, SP/A models seem to be more in accordance with the first three models than with the fifth model.

Explanations of gender differences in our two groups of models are quite distinct. For the first group, gender differences arise through the following routes:

- gender differences in the utility functions $u(x_i)$,

- gender differences in the weighting functions *w(p)*,
- gender differences in reference points.

For the EU model, only the first type of reason is relevant since $w(p_i) = p_i$ is assumed to be objectively given. Reference points are only relevant for PT and SP/A models.

In sections 4.1 to 4.4, utility functions and weighting functions are discussed in detail, and gender differences are attributed to differences in the relative importance of the exogenous variables p_i and x_i for the calculation of u or w, respectively. Such differences translate into differences in the functions' shapes and derivatives. These reasons for gender differences are briefly summarized in column 3 of Table 1.

Table 1:

Differences **Model**	**Value functions** **$V(a_j)$ =**	**Reasons for gender differences:** **Differences in**
EU	$\sum_{i=1}^{N} p_i u(x_i)$	• utility functions u
RDEU	$\sum_{i=1}^{N} \pi_i \, u(x_i)$	• utility functions u • decision weights π_i
PT	$\sum_{i=1}^{N_1} \pi_i^{\,L} \, u(x_i^L)$ $+$ $\sum_{i=N_1+1}^{N} \pi_i^{\,G} \, u(x_i^G)$	• utility functions u • decision weights $\pi_i^{\,L}$ • decision weights $\pi_i^{\,G}$ • reference points
SP/A	$f\,(SP, A)$ $SP = \sum_{i=1}^{N} \pi_i \, x_i$	• decision weights π_i • aspiration levels • f functions
R/R	$g\,(RV, R)$	• *RV* variables • *R* variables • g functions

For the models in the second group, gender differences arise through:

- gender differences in the f or g function,
- gender differences in the *SP* and *A* or *RV* and *R* variables, respectively.

As discussed in section 4.5, differences in the *f* or *g* function appear as differences in shape or derivatives of the function. They imply that for men and women the relative importance of *SP* and *A* or *RV* and *R* differs.

Gender differences in *SP* and *A* or *RV* and *R* may be due to two reasons:

- differences in the explanatory variables for *SP* and *A* or *RV* and *R*,
- differences in the relative importance of these explanatory variables for the calculation of *SP* and *A* or *RV* and *R*.

The decisive point of second-group models is that they deny a clear separability of probability and outcome aspects. If one is sceptical about such separability in real world decision-making, empirical testing of gender differences in risky choices by means of the fifth model presented above would seem appropriate. However, for analytical purposes, it may be better to undertake empirical testing of gender differences using the first group of models. The advantage of such testing would be that probability and sure-outcome effects can be isolated.

Bearing in mind the different gender hypothesis resulting from the decision models described in section 4, the question remains as to which model or combination of models should be chosen by a policy analyst. It is obvious that the models are designed to deal with different issues in the decision process and the analyst must choose accordingly. The first stage, therefore, is to determine whether gender is an issue in a policy debate, or not, and if so to establish the nature of the gender question. Models can then be chosen which address the issue. This implies that a policy analyst or policy decision maker should make use of all pieces of knowledge and presumption concerning origin or nature of gender differences in risky choices.

Before gathering empirical evidence or making predictions, the analyst should decide whether the gender decision context is such that the assumption of separability of probability and sure-outcome aspects is appropriate. Where it is appropriate, one of the first group models should be taken. Where it is not appropriate, the second group models including SP/A would be most relevant. In addition, the policy analyst or policy decision maker should decide on the relative importance of objective, cognitive, and emotional aspects in the gender decision context. If objective aspects dominate, the EU model seems most appropriate. If cognitive aspects including all different biases prevail, RDEU or PT models should be chosen. If motivational aspects dominate, SP/A models would appear appropriate. The more important emotional factors appear, the more suitable it would be to base predictions on gender differences in risky behaviour on R/R models.

To make the above argument more clear, consider the following two examples. Assume for instance that a decision analyst is simply interested in determining the extent to which gender differences in the marginal utility of money affect portfolio choice. Then, the standard EU model or RDEU model might suffice. However, in a health promotion context, the analyst might believe that information affects perceptions of the risk of illness or that emotional factors related to illness in men and women vary. The analyst could then explore the nature of these effects with a PR/R model. If on the other hand aspiration for health is thought to be identical for men and women, and if health promotion decisions are only viewed in terms of gains rather than losses, an RDEU model would seem appropriate. Thus, the choice of models on which predictions about gender differences in risky choices should be based is neither obvious nor unique, but strictly depends on the decision analyst's or policy decision-maker's information and estimates concerning the decision context and the predominant individual choice determinants.

This paper shows how gender can be integrated into formal decision models of choice under risk in order to make sense of the apparent contradictions in the evidence. Only on the basis of explicit decision theoretic modelling can we make sense of existing empirical evidence and develop consistent evidence in the future for policy and organisational choices. We have not attempted to judge whether any one model is a better at modelling or predicting gender differences and we have not explicitly considered decisions under ambiguity. However, these are both interesting developments for future research.

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