

*Studies on Decision Making  
under Risk in the Context of  
Gambling Markets*



**NIKO SUHONEN**

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## **ABSTRACT**

From economic point of view, there are two main reasons to study gambling markets. First, gambling markets today are a major entertainment industry. Second, they offer an authentic environment to research how markets work in general and how people behave under risk. This dissertation is a study on bettors' behaviour in gambling markets. More specifically, we empirically test theoretical assumptions and the market efficiency hypotheses. Chapter 1 is an introduction to the economics of decision making under risk. Chapter 2 is a description of the gambler's utility and the price of gambling. We propose a model where typical gambling behaviour (e.g. betting on horse races) is modelled with the utility of risk, subjective probability, and the utility of money. Chapter 3 empirically analyses market efficiency in betting on Finnish harness horse races. The results imply that the markets are weakly efficient but characterised by the favourite-longshot bias. Chapter 4 is an empirical study based on the theoretical models of expected utility theory and non-expected utility theories. We test the models by using Finnish harness horse racing data. Our empirical results suggest that bettors are risk-averse, but they also have unrealistic views regarding winning probabilities. Chapter 5 empirically analyses gambling markets data in the context of the results of experimental economics. We show that the Allais Paradox and gambling behaviour are related to each other.

Key words: Gambling markets, Expected utility theory, Rank-dependent utility, Favourite-longshot bias

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Väitöskirja

## **ABSTRAKTI**

Talousteorian kannalta on kaksi pääsyötä tutkia rahapelimarkkinoita. Ensiksi, pelimarkkinat ovat suuri viihdeteollisuuden muoto. Toiseksi, pelimarkkinoiden tutkimus tarjoaa mainion reaali maailman tutkimuskentän riskikäyttäytymisen tarkasteluun sekä eri riskiteorioiden testaamiseen ja vertailuun. Tässä väitöskirjassa tarkastellaan ihmisten riskinalaista päätöksentekoa rahapeliin viitekehityksessä. Tutkimuksissa testataan empiirisesti talousteoreettisten mallien oletuksia. Ensimmäinen luku on katsaus riskinalaisiin päätösteorioihin. Toinen luku on kuvaus rahapelaajien käyttäytymisestä, pelaamisesta saatavasta hyödystä ja rahapelin hinnan määräytymisestä. Kolmas luku käsittelee empiirisesti markkinoiden tehokkuutta Suomen ravipelimarkkinoilla. Tulosten mukaan markkinat ovat pääosin tehokkaat, mutta pelaajat sijoittavat yllättäjiin enemmän kuin olisi odotusarvon mukaisesti kannattavaa (ns. yllättäjän harha). Neljäs luku testaa empiirisesti odotetun hyödyn ja vaihtoehtoisen ns. ei-odotetun hyödyn mallien oletuksia Suomen ravipeliaineistolla. Tulokset viittaavat siihen, että pelaajat ovat riskinkaihtajia, mutta heidän subjektiiviset käsityksensä todennäköisyyksistä poikkeavat objektiivisista. Luvussa viisi analysoidaan pelaajien käyttäytymistä kokeellisen talousteorian viitekehityksessä. Tulosten mukaan pelaajien käyttäytymisellä ravipeleissä on yhteneväisyyksiä ns. Allaisin paradoksin kanssa.

Asiasanat: rahapelimarkkinat, odotetun hyödyn teoria, järjestyksestä riippuva odotetun hyödyn teoria, yllättäjän harha

# Preface

Choosing a topic for my dissertation was quite a risky bet. When I started the project in 2006, gambling markets studies were scarce in the University of Joensuu. But sometimes in life, you do not choose but something chooses you. In my case, it was the favourite-longshot bias (FLB) which chose me. Nowadays, however, I and FLB know each other well enough and I think that it is now my turn to decide what we want to do in the future, break up or stay together. Although my topic was in some sense an “exotic” one, people around me were supportive and encouraging. Therefore, I want to express my gratitude to all those who made this accomplishment possible.

First of all, I would like to thank my supervisors Professor Mika Linden and Dr. Timo Tammi for their guidance during this project. Without their patience and sympathy, everything would have been much harder. I wish to thank professors, lecturers, researchers, and administrative staff of the faculty of Social Science and Business Studies. I also thank Professor Juha Alho for his constructive feedback concerning my dissertation. I am indebted to Professor David Forrest for his comments and insightful discussions during the visit in the University of Salford in autumn 2010. I am grateful to the pre-examiners of my thesis Professor Antti Kanto (University of Tampere) and Professor Hannu Vartiainen (University of Helsinki). Their comments improved the thesis. I also thank Professor Timo Kuosmanen (Aalto University) for serving as the opponent in the public examination.

I wish to acknowledge my friends and fellow doctoral students Mika Louhelainen, Mika Kortelainen, Anssi Kähkönen, Tuukka Saarimaa, and especially Jani Saastamoinen who helped me by providing data. Hopefully, our cooperation will continue one way or another.

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I thank my parents, Yrjö and Emma, for their support over the years. Finally, my deepest gratitude goes to Minna, who has always encouraged me during my deep moments of hell and high moments of heaven on this journey.

Joensuu, December, 2011

Niko Suhonen

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# 1 Introduction

Every day we have to make choices which include risk and uncertainty. Do we buy home insurance to cover damage due to fire? In which financial instrument, stocks or government bonds shall we invest our money? Is it a good bet to drive through red traffic lights? In fact, it is very hard to find an ordinary day when we do not need to make some risky or uncertain choices. But what does the word “risk” actually mean? The Oxford English Dictionary defines risk as “([e]xposure to) the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility.” Thus, risk is the possibility of an event which is unavoidable or could be unpleasant. Generally, we try to avoid risk, i.e. we are risk-averse. On the other hand, if we choose the risky option and the unpleasant event does not occur, we will usually be rewarded (e.g. we save money or time). Hence, we try to estimate the probabilities of expected losses and choose an option, risky or less risky, whichever is best for us.

One target of decision making theories is to model how individuals behave under risk and uncertainty. This modelling is based on two critical concepts: probabilities and outcomes. Basically, it means that modelling individuals’ behaviour, in a general sense, very closely resembles decisions in the context of gambling. That is, decision-makers win and/or lose some amount of money (outcome) with a given probability. In this dissertation we study decision making under risk from the perspective of gambling markets.

Why gambling? It seems that gambling is a part of human nature. The classical legend tells us that Zeus, Hades and Poseidon split the Universe up by sharing heaven, hell and the sea by a throw of the dice. Also, it has been claimed that the Roman soldiers cast lots for the garments of Christ after His crucifixion. In the context of probability theory, gambling has played a significant role. The mathematicians Fermat and Pascal (in their contribution) established the basic principles of probability. They considered the specific issues of odds calculation that had been presented to them by gamblers.<sup>1</sup> In addition, from the economic point of view, there are two main reasons to study gambling markets. First, gambling markets today are a major entertainment industry. Second, they offer an authentic environment to research how markets work in general and how people behave under risk.

Traditionally, gambling markets offer opportunities to bet on sports events and horse racing, but also to play casino games (e.g. roulette and Black Jack)

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<sup>1</sup> In 1654, the Chevalier De Mere, was puzzled by a popular dice game. The game consisted of throwing a pair of dice 24 times; the problem was to decide whether or not to bet even money on the occurrence of at least one “double six” during the 24 throws. A well-established gambling rule led De Mere to believe that betting on a double six in 24 throws would be profitable, but his own calculations based on many repetitions of the 24 throws indicated just the opposite.

likewise various lotteries and slot machines. However, nowadays one can bet on almost anything<sup>2</sup>: for instance, who wins the elections or the Eurovision Song Contest. Since these markets are alive and well, there must also be demand. To shed some light on the scale of betting, we present some facts and figures on gambling markets in Finland. According to the Yearbook of Finnish Gambling 2009, it is estimated that 87 per cent of people over 15 years of age have engaged in gambling at some point in their lives. Gambling therefore provides the majority of people with pleasure or entertainment, but at the same time it is estimated that about three per cent of population have had gambling problems during the last 12 months<sup>3</sup>. To control adverse effects of gambling, the gambling markets in Finland are regulated by state-owned monopolies. There are three state-owned gambling companies: Veikkaus (lotteries, betting on sports events), RAY<sup>4</sup> (slot machines, Casino games), and Fintoto (betting on horse racing).

According to the statistics of the gambling companies, we know that turnovers increased in the period 2004-2008 (Yearbook of Finnish Gambling 2009). In total, the turnover in 2008 was almost 8.6 billion Euros. Thus the average amount of bets per person per year (over 15 years of age) in 2008 was almost 2,000 Euros. However, this does not tell us the right information on total spending on gambling because very often we get back the amount of our bet (win) and bet it again. The actual amount of total spending is the companies' profit before taxes and costs. That was 1.5 billion Euros in 2008. This amount indicates that the average amount of spending per person is about 330 Euros. Overall, it seems that people gamble and are prepared to pay for this enjoyment, but there are also some adverse effects, such as gambling addiction. An understanding of the operation of markets and gamblers' behaviour gives us a tool to analyse policy alternatives, undesired side effects, market regulation, and incentive designs.<sup>5</sup>

First, gambling is a puzzling phenomenon from the perspective of economic theory. Conventional decision theory assumes that people try to avoid risk, and they buy insurances, for instance. Hence, voluntary participation in activity that constitutes a risky situation with a negative expected value (such as betting) is not expected at all. However, gambling itself may not be wealth-oriented but instead motivated by the pleasure of gaming. Thus, from the perspective of entertainment, game participation can be rationalized. This aspect of gambling is usually ignored in the economic literature. The topic is discussed in detail in Section 2.6.

Second, bettors' behaviour in gambling markets can be used as a test for different decision theories under risk and market efficiency. Usually, in betting markets there is a large number of gamblers with potential access to rich information sets, and each bet has a well-defined endpoint at which its value becomes certain. This gives us an opportunity to estimate econometrically the assumptions of de-

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<sup>2</sup> In fact, some betting firms offer the opportunity to bet on everything, e.g. when the first human being will land on Mars.

<sup>3</sup> It is estimated that about a third of these people are pathological gamblers.

<sup>4</sup> Actually, RAY (Finland's Slot Machine Association) is not a company but an association of public utility. Veikkaus and Fintoto are limited companies owned by the state.

<sup>5</sup> On the current development of gaming markets, see Virén (2008).

cision making theories. Moreover, the information issues, like the hypothesis of market efficiency, can be tested by using the historical data of results.

This dissertation is a study on bettors' behaviour in gambling markets. More specifically, we empirically test theoretical assumptions and the market efficiency hypotheses. The main contribution of the dissertation is the articles in Chapters 2 to 5. Chapter 2 is a description of the gambler's utility and the price of gambling. We propose a model where typical gambling behaviour (e.g. betting on horse races) is modelled with the utility of risk, subjective probability, and the utility of money. Chapter 3 empirically analyses market efficiency in Finnish betting on horse races. We also introduce a testing procedure which is based on the actual winning odds rather than commonly used probability estimates. Chapter 4 is an empirical study based on the theoretical models of expected utility theory and non-expected utility theories. We test the models by using Finnish harness horse racing data. Chapter 5 empirically analyses gambling markets data in the context of the results of experimental economics. We show that the Allais Paradox and gambling behaviour are related to each other.

The rest of the introductory chapter is organised as follows. First we review decision making theories under risk and uncertainty. In Section 3 we discuss market efficiency conditions from the perspective of gambling markets. Section 4 presents a summary of articles.

# 2 Theories of Decision Making Under Risk and Uncertainty

## 2.1 BACKGROUND

The idea of the expected utility theory (from now on EUT) was first proposed by Daniel Bernoulli (1738). Bernoulli was puzzled by the problem of how much a rational individual is prepared to pay to take a gamble. The most common conception was that gamblers could pay the expected monetary value of the gamble but nothing more. However, Bernoulli gave a following counterexample: suppose that we toss a coin repeatedly until we get heads. Our winning sum is  $2^n$ , where  $n$  is the number of throws until we get the first heads. As there is always a non-zero probability that  $n$  can be very large the winning sum can increase infinitely.<sup>6</sup> This is the so-called St. Petersburg gamble or paradox. Bernoulli concluded that individuals are only prepared to pay a small amount of money for such a gamble. In other words, individuals change money bets for some kinds of “utilities”.

Much later John von Neumann and Oskar Morgenstern (1944) developed expected utility theory. This is also called *von Neumann-Morgenstern* EUT. The main aspects of EUT are the preferences and the axioms which determine decisions under risk and uncertainty.<sup>7</sup>

## 2.2 EXPECTED UTILITY THEORY

To comprehend the general idea of EUT, assume a consequence or an outcome of some action or choice which happens with some probability. These consequences, broadly speaking, may be death, illness, victory, etc. However, assume that the consequences are a list of measurable monetary values. These mutually exclusive consequences are associated with the probability distribution in which probabilities are non-negative and add up to one. Now, the consequences and probabilities together present a vector which is called a *prospect* or *gamble*. Thus, the prospect is to be understood as a list of consequences with associated probabilities.

Basically, EUT can be derived from three separate axioms with the monotonic-

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<sup>6</sup> Note that this only works if the amount of gambling cash is infinity.

<sup>7</sup> Traditional decision theories distinguish between the concepts of risk and uncertainty. Decision making under risk means that the outcome probabilities are known, whereas in decision making under uncertainty these probabilities are unknown. However, most decisions are made in the middle field between known and unknown probabilities. Therefore, we do not distinguish between decisions under risk and uncertainty.

ity assumption: ordering, continuity, and independence<sup>8</sup> (for more detail, see e.g. Starmer 2000). Now, assume that axioms, preferences over gambles, can be represented by a function which gives a real-valued index to each gamble. This function operates between prospects, such that an individual will choose the first gamble over the second gamble if and only if the value of the index of the first gamble is no less than the value of the index of the second gamble. We also assume that an individual maximizes the function index. In practice, this index can be calculated by taking the weighted average of the utility of outcomes, whereby the incorporated weights are precisely the true probabilities of receiving the corresponding outcomes. This means that the utility function measures outcomes in a real-value and comparable form. We assume that the utility function is continuous, monotonous and at least twice differentiable. The shape of the utility function has behavioural interpretations: a concave utility function means risk aversion and linear utility function indicates risk-neutrality, whereby a convex function means risk-seeking.<sup>9</sup>

In EUT we usually assume that individuals are risk-averse. This implies that an agent with concave utility function will always prefer a certain amount  $x$  to any risky prospect with an expected value equal to  $x$ . Moreover, EUT considers risky decisions from the perspective of final states (which include asset position) rather than just gains or losses.

One application of EUT is subjective expected utility theory (SEUT), which is also called Bayesian decision theory. SEUT was first developed by Savage (1954). Savage obtained the basic ideas from Ramsey (1931), de Finet (1937), and von Neumann & Morgenstern (1944). EUT axioms and definitions also play an important role in SEUT. However, the main difference is that in EUT probabilities are based on objective verifiable information, whereas in SEUT a decision-maker perceives probabilities subjectively: an individual evaluates the probabilities of consequences *a priori* with his or her personal knowledge or beliefs and updates (*posterior*) his or her beliefs as a learning process.

For example, suppose that we ask an individual about the probability of a toss, when we flip an unbiased coin. At first, the gambler's *a priori* estimate of the toss probability is 0.3. However, the gambler is a rational decision-maker and decides to conduct coin-flipping trials before answering. As the decision-maker has flipped the coin long enough, he or she notices that the *posterior* probability is closer to 0.5 than 0.3. Therefore the gambler decides to answer almost surely that the probability of the toss is 0.5.

As regards a utility function, Savage (1954) pointed out that the function must be bounded at least from above. The reason is simple: if the function was not bounded, the St. Petersburg paradox would not vanish. Furthermore, Savage (1954) left open the possibility that utility as a function of wealth may not be concave, at least in some intervals of wealth. The possibility of non-concave segments of the utility function is also found in Markowitz (1952), and in Friedman & Savage (1948).

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<sup>8</sup> The ordering axiom includes both completeness and transitivity. Note that when we discuss individual rationality, we imply that an individual behaves according to the above axioms.

<sup>9</sup> In the context of gambling markets, we have to assume convex utility function, i.e. risk-seeking behaviour.

## 2.3 CRITICISM OF EXPECTED UTILITY THEORY

EUT has come in for harsh criticism since the early 1950s. Often the criticism has been motivated by experiments, where it has been observed that decision-makers systematically behave against predictions of EUT.

*The Allais Paradox.* The possibly most famous paradox was introduced by Maurice Allais (1953). It can be presented as follows. First imagine choosing between two prospects: The first option ( $s_1$ ) is sure to yield one million. The second ( $r_1$ ) will yield five million with a probability 0.1, one million with a probability 0.89, and nothing with a probability 0.01. After the first decision, with the same logic, you choose between another two prospects. Now first option ( $s_2$ ) gives one million with the probability 0.11 and otherwise nothing. The second ( $r_2$ ) gives five million with the probability 0.10 and otherwise nothing. Now, because expected values of these prospects are  $E[s_1] < E[r_1]$  and  $E[s_2] < E[r_2]$ , according to EUT formulation, the preference  $s_1 \succ r_1$  should entail the preference  $s_2 \succ r_2$ , and *vice versa*. However, Allais expected that people might choose  $s_1$  in the first choice, because they are sure to become millionaires. Likewise, as the second choice they might opt for  $r_2$ , because the probabilities of winning are similar, but the prizes are very different between  $s_2$  and  $r_2$ . Allais' conclusion was correct, because the above phenomenon has been observed in many experiments (e.g. Kahneman & Tversky 1979). The above example is the famous Allais paradox and is more generally known as the *common consequence effect*.

An interesting episode occurred in 1952, when Savage, who was a strong supporter of EUT, participated in a test organized by Allais.<sup>10</sup> It happened that Savage was one of those who chose as Allais expected. When Savage realized that his choices were contrary to EUT, he wanted to revise his choices. He claimed that he had been misled and a more cautious reading of the problem would have been sufficient to avoid the mistake.

*Common Ratio Effect.* Another interesting phenomenon is the *common ratio effect*, which was also discovered by Allais. Suppose that we choose between two gambles. The first gamble gives 3000 € with certainty. The second one gives 4000 € with the probability 0.8 and otherwise nothing. After that, we once more choose between gambles such that the first one gives 3000 € with the probability 0.25, otherwise nothing, and the second one gives 4000 € with the probability 0.2, otherwise nothing. The evidence from experiments suggests that most people select from the first choice the sure winning prize and from the second one they opt for 4000 € (e.g. Kahneman & Tversky 1979). However, this is inconsistent with EUT.

*Other Problems and Paradoxes.* During the last 50 years, other paradoxes have been found as well. One of these is a phenomenon called preference reversal. This was reported first by the psychologists Lichtenstein & Slovic (1971) and it was later brought to the attention of economists by Grether & Plott (1979). Preference reversal is a behavioural tendency for the revealed preference ordering of a pair of alternatives to depend on the process used to elicit it. Another paradox is called

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<sup>10</sup> See more by Gollier (2001).



the Ellsberg paradox (Ellsberg 1961). Ellsberg showed that decision-makers could be influenced by extra information so that they changed their preferences from the certain case to the uncertain without a change in probabilities or in winning prizes. For more details on these problems and others, see for example Bardsley et al. (2010), Camerer (1995), Hargreaves et al. (1992), and Gärdenfors & Sahlin (1988).

## 2.4 APOLOGIA FOR EXPECTED UTILITY THEORY

Many new decision theories have emerged in response to the results of experiments. Consequently, the new theories have challenged EUT. Do people really behave as EUT predicts, or can we explain behaviour by psychological aspects such as fear, enjoyment, disappointment, etc.? EUT has been defended against criticism. It has been argued that learning takes place in the real market environment that does not occur in experiments (e.g. Savage 1954). On the other hand, the learning process itself can be interesting (see Binmore 1999).

However, regardless of the criticism, we can refer to the methodology of Lakatos. Since none of these alternative theories can explain all paradoxes, and because none of them is clearly better than EUT in general, we cannot refute EUT (Hausman 1992). On the other hand, it would not be reasonable to refute all alternative theories either. Hence many economists think that we have one *core* theory, in this case EUT, surrounded by alternative theories, which can explain exceptional phenomena conflicting with the EUT point of view (e.g. Plott 1995). As a result of discussion, some economists have perceived that it is meaningful to classify decision theories into different categories.

*Normative Theories.* The purpose of normative theories is to express how people *should* behave when confronting risky decisions. Thus the behavioural models based on EUT stress the rationality of decisions. We are not interested so much in how people behave in real life or in empirical experiments.

*Descriptive Theories.* From the descriptive point of view, we are concerned with *how* people make decisions in real life. The starting point for these theories has been in empirical experiments, where it has been shown that people's behaviour is inconsistent with the normative theories. These theories are, for example, prospect theory and regret theory. We present them in greater detail in the next sections.

## 2.5 DESCRIPTIVE MODELS

New descriptive theories have tried to explain paradoxes and decision making problems. Perhaps the best-known theories are the regret theory and the prospect theory. In fact, it seems that the prospect theory by Kahneman & Tversky (1979) really challenges EUT.<sup>11</sup> However, there are also several other theories, for example, general-

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<sup>11</sup> A seminal work on prospect theory by Kahneman & Tversky (1979) is the second most cited paper in economics (Kim et al. 2006).

ized expected utility theory (Machina 1982). For an extensive historical overview, see Starmer (2000). Next we briefly introduce regret theory and prospect theory.

### 2.5.1 Regret Theory

The descriptive regret theory omits the assumption of preference transitivity. The descriptive regret theory was proposed simultaneously by Bell (1982), Fishburn (1982), and Loomes & Sugden (1982, 1987). The main idea behind the theory is that, when making decisions individuals take into account not only the consequences that *may* result from the action chosen, but also how each consequence compares with what they *would have experienced* under the same state of the world had they chosen differently. Thus the consequences are not *independent* of each other, and it is possible that choices are in contradiction with the transitivity assumption. However, people maximize utility in the sense that they aspire to avoid regret or disappointment.

For example, suppose an individual is gambling and buying insurance simultaneously. Thus, if an individual is globally risk averse or a risk lover, the behaviour is inconsistent with EUT. The regret theory explains the phenomenon in the following manner: Individuals buy insurance because they think that if they do not buy, the situation in case of an accident will be bad. Likewise, individuals also regret if they do not gamble for a small amount, because in case of winning, they might “lose” a huge prize. In conclusion, regret theory is based on comparison between “what is” and “what might have been”.

### 2.5.2 Prospect Theory

Prospect theory and cumulative prospect theory were first formulated by Kahneman & Tversky (1979) and Tversky & Kahneman (1992). They approached decision making under risk from the perspective of traditional behavioural sciences. The findings by Kahneman & Tversky (1979) and Tversky & Kahneman (1981, 1986) in their experiments are the groundwork for prospect theory. The backbones of prospect theory and its main contrasts with EUT follow below.

*Probability Weighting Function.* The function can be described as follows: an individual changes probabilities, which may be true probabilities, to his or her beliefs based on true probabilities, i.e. the probability weighting function weights true probabilities. In experiments it has been noted that people typically overestimate low probabilities and underestimate high probabilities (Kahneman & Tversky 1979). The point at which probabilities change from being overweighted to underweighted has often been estimated to be between 0.3 and 0.4 (see, e.g. Johnson 2004; Prelec 1998). Figure 1 illustrates the shape of a typical probability weighting function.

Kahneman & Tversky (1979) used the first version of prospect theory, the probability weighting model, which violated the monotonicity assumption (see more, Prelec 1998). However, the rank-dependent representation, first developed by Quiggin (1982), avoids the problem of monotonicity.<sup>12</sup> Moreover, Tversky & Kahneman (1992) used a version called cumulative prospect theory, or a cumulative weighting function, which was consistent with the monotonicity assumption and which may differ for gains and losses.

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<sup>12</sup> Actually, the rank-dependent utility model is EUT with the probability weighting.

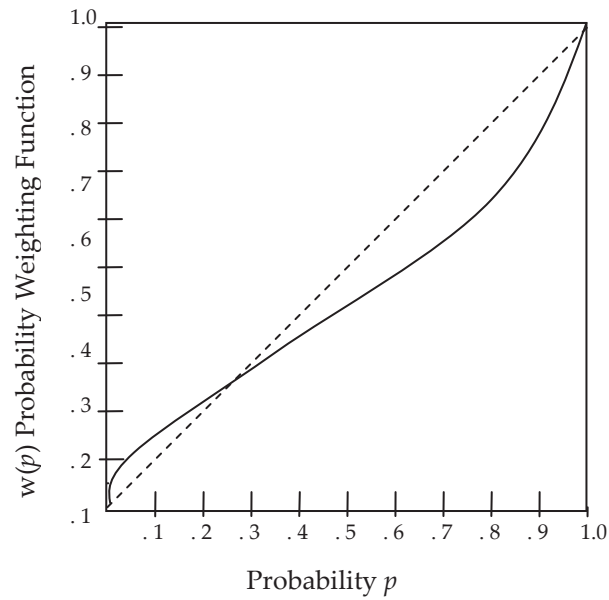


Figure 1. A Typical Probability Weighting Function.

*Value Function.* Another deviation with EUT is the properties of the value function. The value function assigns utilities to outcomes like EUT (utility function), but it has three main characteristics:

- 1) Defined on deviations from the reference point
- 2) Concave for gains and convex for losses
- 3) Steeper in the domain of losses.

Figure 2 illustrates these properties.

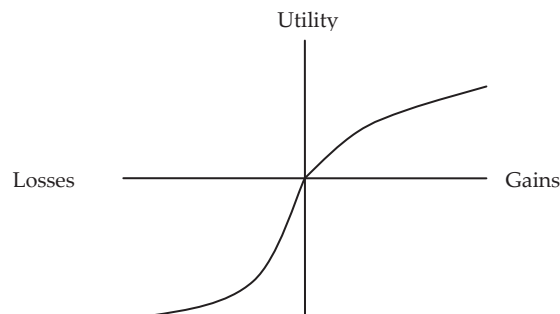


Figure 2. The Valuation of Outcomes in Prospect Theory.

First, Kahneman & Tversky (1979) proposed that only consequences matter, not the wealth level. That is, the value function is defined on deviations from the reference point. Second, Kahneman & Tversky (1979) assumed that the function is concave above the reference point and convex below it. These properties reflect the principle of *diminishing sensitivity*. The impact of a marginal change will therefore decrease as we move further away from the reference point. For example, relative to the reference point the difference between a gain of 10 € and 20 € will seem larger than the difference between gains of 110 € and 120 €. Finally, they assumed that value function is steeper for losses than for gains. This is the principle of loss aversion, which implies that losses loom larger than corresponding gains.

We presented previously an example of an individual who buys insurance and gambles simultaneously. The prospect theory explains such behaviour in that an individual overestimates low probabilities and underweights high probabilities. Thus simultaneous gambling and buying insurance are not necessarily incompatible.

## 2.6 UTILITY OF GAMBLING

Descriptive models can explain gambling to some extent, but there are still some pitfalls, e.g. in prospect theory the loss-averse behaviour excludes some gaming types. Overall, it can also be argued that gambling is not wealth-oriented but rather motivated by the pleasure of gambling. The utility of gambling is most often ignored in the economic literature. This is surprising. One illustrative motivation for the utility of gambling is given by Conlisk (1993):

*“Economists do not model food preferences solely in terms of the nutritional consequences for health, or clothing preferences solely in terms of protection against the elements, or transportation preferences solely in terms of physical conveyance. Similarly, economists need not model gambling solely in terms of consequences for wealth.”* (pp. 256).

Furthermore, Conlisk (1993) proposed a model of the pleasure of gambling which was an expected utility model for a risk-averse bettor appended by “a tiny utility of gambling”<sup>13</sup>. Thus, gambling markets can be seen as entertainment or consumption where bettors accept the negative expected value as a fee for enjoyment.

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<sup>13</sup>However, Conlisk (1993) noted that model could equally well be appended to models of risky choice other than the expected utility model.

# 3 Market Efficiency

## 3.1. INFORMATION EFFICIENCY

In economics the term “efficiency” is used very often. Although efficiency has many meanings in different contexts, it refers to a situation in which it is not possible to increase the well-being of any one person without reducing the utility of another. This is usually known as Pareto Efficiency. However, in the analysis of betting markets, and financial markets more generally, the examination of efficiency concerns the information dimension. The concept of information efficiency in a market is referred to as the so-called “efficient market hypothesis”. The most famous definition of efficient market hypothesis can be found in Fama (1991):

*“I take the market efficient hypothesis to be the simple statement that security prices fully reflect all available information.”* (pp. 1575).

In other words, the observed market price reflects all relevant market information present and past and there are no systematic prediction errors<sup>14</sup>. Now, market efficiency can be categorized into three definitions: 1) *weak* form information is limited to the price history; 2) *semi-strong* information is limited to publicly available information; 3) *strong* form information includes all known relevant information, including private information.

In gambling markets, information plays a crucial role because the odds refer to the gambling market’s estimates of each outcome’s likelihood of winning<sup>15</sup>. Therefore, Thaler & Ziemba (1988) suggested that the efficient market hypothesis (ME) in the context of gambling markets can be presented as:

1. *Weak ME*: Do some systematic bets have positive expected value?
2. *Strong ME*: Does every bet have the same expected value?

Weak form market efficiency detects the possibility to make a profit by using information on historical results. On the other hand, strong efficiency demands that every bet should have the same expected profit (or loss). In fact, these hypotheses are testable using betting market data<sup>16</sup>.

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<sup>14</sup> The efficient market hypothesis is usually misunderstood in economic debate: a hypothesis does not predict which final state will occur, it merely reflects on all the necessary information and proposes correct probabilities for the final specific states.

<sup>15</sup> Especially in a pari-mutual system in which gamblers’ winning bets share the prize money from all bets and, therefore, the pool shares represent the odds for every possible outcome.

<sup>16</sup> For a discussion of market efficiency from the perspective of gambling markets, see also Vaughan Williams (2005).

## 3.2 INEFFICIENCIES IN GAMBLING MARKETS

The best-known and well-documented inefficiency in gambling markets is the *favourite-longshot bias* (FLB): the favourites are under-bet while the longshots are over-bet (e.g. Ali 1977)<sup>17</sup>. As a result, if gamblers bet systematically on the favourites, they do not lose as much as gamblers who bet on the longshots. This may indicate that at least the strong efficiency condition is violated because the expected return is not a constant. Furthermore, it is possible that the favourite-longshot bias is driven by behavioural aspects (e.g. risk-loving attitude or probability weighting).

However, efficiency test values may be contaminated by other types of inefficiency. The *End of the Day Effect* is an interesting, although not extensively documented, regularity. At the end of the day, gamblers' behaviour becomes more aggressive. In practice, this means that the favourite-longshot bias is especially strong in the last rounds of the game (see McGlothlin 1956; Ali 1977; Asch et al. 1982). This is consistent with the assumption of Prospect Theory that bettors are loss-averse and risk-loving below the reference point. Most bettors have lost during the game day and the last races offer an opportunity to win back their money.

The *Gambler's Fallacy* is an erroneous belief concerning the probability of an independent event when the event has recently occurred<sup>18</sup>. This is well documented in experiments and in real gambling markets as well. For instance, Clotfelter & Cook (1993) noted that in lottery gambling gamblers rarely chose the number which occurred in the previous round. Croson & Sundali (2005) conducted field experiments in casinos (roulette) and found evidence that supports the assumption of the gambler's fallacy.

Consequently, we can use gambling market data to test the assumptions of decision making theories (e.g. loss-averse behaviour or probability weighting) or the paradoxes from the experimental literature (e.g. the Allais Paradox or the gambler's fallacy). Alternatively, we can find some other kind of regularities in gambling markets data that are unobserved in theory or experiments.

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<sup>17</sup> The bias was first noted by Griffith (1949).

<sup>18</sup> There is also another fallacy that is very close to the gambler's fallacy, namely the *hot hand bias*. That is, if an individual has won in the past, then whatever they choose to bet on is likely to win in the future.

# 4 *Summary of Articles*

## **4.1 CHAPTER 2: PRICE OF GAMBLING AND BETTORS' BEHAVIOUR ON UNFAIR GAMES**

The first essay (co-authored with Mikael Linden) is a description of risky and uncertain decision making in the framework of gambling. Several reasons indicate that gambling behaviour is a consumption type activity, similar to enjoying a theatrical performance, for instance. Thus it is evident that gambling behaviour is more than just risky choices.

We argue that it is reasonable to assume that the price of gambling is the take-out rate or the expected loss of a game. In theoretical studies, the utility of gambling has been modelled by two separate utility functions (e.g. Conlisk 1993). We propose an alternative approach, in which we avoid the additional utility function, and the price of gambling (the take-out rate) is taken into account as well. Nevertheless, we also show that even when the price of gambling is the expected loss, the risk-averse gambler with an unbiased perception of probabilities should never participate in such gambles that betting markets offer. In addition, we suggest that participation and typical gambling behaviour (e.g. betting on horse races) can be explained by an approach that includes the utility of risk, subjective probability, and the utility of money. This is due to the fact that the gambling markets constitute an environment where risky choices can be measured only by probabilities. We are aware that our approach needs more theoretical research and must be tested empirically. However, the approach may shed some interesting light on the literature on gambling markets.

## **4.2 CHAPTER 3: MARKET EFFICIENCY IN FINNISH HARNESS HORSE RACING**

The second essay is an empirical study of market efficiency in Finnish harness horse racing. The well-known inefficiencies reported in the literature are the favourite-longshot bias and the end of the day effect (e.g. Ali 1977; Asch et al. 1982). We also test the gambler's fallacy assumption, usually reported in lotteries and Casino games (Clotfelter & Cook 1993; Croson & Sundali 2005). Although most horse racing studies are based on on-track betting information, our data also contains information that coincides with the transition from on-track gambling to Internet (off-track) betting<sup>19</sup>. It is possible that Internet gambling affects infor-

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<sup>19</sup> In fact, Internet betting on horse races has increased sharply since the early 2000s. For instance, during the years 2004 and 2005, Internet gambling increased by over 46 % (Yearbook of Finnish Gambling 2009).

mation efficiency in gambling markets because it provides easier access to casual gambling.

We briefly first discuss definitions of market efficiency, and well-known inefficiencies. Next we present the methods used to test betting market efficiency in the literature. We introduce a testing procedure which is based on the actual winning odds rather than commonly used probability estimates. Consequently, the confidence intervals used to test the hypotheses differ from earlier approaches.

Our results imply that markets are weakly efficient but characterised by the favourite-longshot bias. That is, there is no opportunity to make any profits using past data. We also conclude that the transition from on-track betting to off-track, and especially to the Internet, does not remove the FLB. However, no meaningful evidence for other “anomalies”, namely the end of the day effect and the gambler’s fallacy, was found. This is a minor drawback for the prospect theory assumption of loss-averse behaviour. In fact, consistent with the results in Snowberg & Wolfers (2010), if there was evidence of loss aversion in earlier data sets, it no longer appears in the more recent data. Thus, in our data, it is possible that this element has disappeared during the transition from on-track betting to off-track betting because gambling choices have no clear end point. Finally, the alternative procedure did not make any remarkable difference to the inferences made under standard methods because FLB is an obvious phenomenon regardless of the testing method. However, the approach presented might be useful for smaller data sets or other areas of research.

### **4.3 CHAPTER 4: MODELLING BETTORS’ RISK BEHAVIOUR IN HARNESS HORSE RACING: THE UNCERTAINTY FUNCTION APPROACH**

The third essay reports an empirical study based on the theoretical models of expected utility theory and non-expected utility theories. As noted earlier, gambling markets (e.g. betting on horse races) are characterised by FLB. Explanations for FLB have been based on expected utility theory as well as on non-expected utility theories. The classical EUT explanation of FLB is that the bettors are risk-lovers. On the other hand, for instance, prospect theory proposes that decision-makers overweight the low probabilities and underweight the high ones, thereby arriving at FLB.

We test different specifications of probability weighting functions with a general binary outcome model using Finnish harness horse racing data. This also allows testing of the implications of expected utility theory and non-expected utility theories. Overall, our empirical results suggest that bettors are risk-averse, but they also have unrealistic views regarding winning probabilities. These findings are important because they reject the conclusion that risk-loving explains the bettors’ behaviour in racetrack betting. Furthermore, this implication is consistent with non-expected utility theories rather than with expected utility theory.



#### **4.4 CHAPTER 5: DOES ALLAIS PARADOX EXPLAIN GAMBLING BEHAVIOUR? EVIDENCE FROM HORSE RACE BETTING**

The fourth essay (co-authored with Jani Saastamoinen and Mikael Linden) analyses empirical gambling markets data in the context of the results of experimental economics. Moreover, we test for the heterogeneity in the data that affects the risk behaviour. That is, the bettor's behaviour may be conditional on different factors, such as time, place, and race characteristics. The theoretical approach is motivated by the papers by Prelec (1998) and Diecidue et al. (2009), and the empirical testing is closely related to Jullien & Salanié (2000).

The criticism of EUT has been motivated by the experiments in which decision-makers systematically violate the predictions of EUT (e.g. Allais 1953; Kahneman & Tversky 1979). However, it is not clear whatever these experiments reflect the real-life situations. In this paper we show that in real-life situations decision-makers behave under risk as proposed in the Allais experiments (Allais 1953). More precisely, our empirical findings from gambling markets satisfy the preference relation of the common consequence effect and common ratio effect in the experimental literature over fifty years ago. Furthermore, our results suggest that bettors' behaviour is invariant in time and in the scale of betting. In other words, all that matters is the attitude towards risk and uncertainty.

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