Charles University

Faculty of Social Sciences
Institute of Economic Studies

MASTER'S THESIS

Hormones and Competitive Behavior

Author: **Bc. Zdeněk Sýkora**

Supervisor: **PhDr. Lubomír Cingl, Ph.D.**

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently; using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, May 10, 2018

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Abstract

The thesis aims to contribute to the literature on the biological underpinnings of important economic behaviors. Financial markets can become dangerously unstable from many reasons such as the hormones contained in our bodies. We primarily focus on the effect of basal testosterone and cortisol on willingness to compete and risk taking. We also investigate their interaction called the dual-hormone hypothesis, because it has not been sufficiently analyzed and replicated so far. We run a controlled laboratory experiment with 96 university students and have gender-balanced dataset, thus we can also examine gender differences. We find no support that higher testosterone increase willingness to compete in men as opposed to most of the recent literature. Moreover, higher levels of testosterone decrease competitiveness but only for women. We further find positive effect of the 2D:4D ratio for women and negative effect of trait anxiety for men on competitiveness. There are also substantial gender differences in competitive and risk taking behavior. We cannot confirm the dual-hormone hypothesis for willingness to compete. But we find significant support for the dual-hormone hypothesis for risk taking for women and with negative effect of testosterone on risk taking. The effects stay robust even after controlling for other influential variables.

JEL Classification	C12, C91, D91, G41
Keywords	hormones, testosteron, cortisol, risk taking, competitiveness, 2D:4D, dual-hormone hypothesis

Author's e-mail	71229303@fsv.cuni.cz
Supervisor's e-mail	lubomir.cingl@gmail.com

Abstrakt

Cílem této práce je přispět do výzkumu ohledně biologických základů důležitého ekonomického chování. Finanční trhy se mohou stát velmi nestabilním prostředím z mnoha důvodů, jako jsou například hormony obsažené v našem těle. Především se zabýváme vlivem bazálního testosteronu a kortizolu na ochotu soutěžit a riskovat. Také se zaměřujeme na interakci těchto hormonů, která se obvykle označuje jako dual-hormon hypotéza, protože dosud nebyla dostatečně analyzována a replikována. Data jsme získali z kontrolovaného laboratorního experimentu s 96 vysokoškolskými studenty. Naše data jsou genderově vyvážená, tudíž na rozdíl od ostatních můžeme také zkoumat genderové rozdíly ve vztahu k soutěživosti a riskování. Dle našich výsledků, nemůžeme potvrdit, že vyšší testosteron zvyšuje ochotu soutěžit u mužů, oproti většině současné literatury. Navíc dokonce vyšší hladina testosteronu snižuje soutěživost, ale pouze u žen. Dále naše data ukazují pozitivní efekt 2D:4D poměru u žen a negativní efekt dlouhodobé úzkosti u mužů ve vztahu k soutěživosti. Existují také výrazné rozdíly mezi pohlavími v soutěživém a rizikovém chování. Nemůžeme však potvrdit dual-hormon hypotézu ve vztahu k soutěživosti. Zjistili jsme ale významnou podporu pro dual-hormon hypotézu ohledně riskování u žen a s negativním vlivem testosteronu na riskování. Efekty zůstávají robustní i po přidání dalších významných proměnných.

Klasifikace	C12, C91, D91, G41
Klíčová slova	hormony, testosteron, kortizol, riskování, soutěživost, 2D:4D, dual-hormon hypotéza

E-mail autora	71229303@fsv.cuni.cz
E-mail vedoucího práce	lubomir.cingl@gmail.com

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Acronyms

2D:4D	Second-to-fourth digit ratio
NEO	Neuroticism-Extraversion-Openness
OLS	Ordinary Least Squares
TSST-G	Trier Social Stress Test for Groups

Master's Thesis Proposal

Author:	**Bc. Zdeněk Sýkora**
Supervisor:	PhDr. Lubomír Cingl, Ph.D.
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Proposed Topic:

Hormones and Competitive Behavior

Motivation:

It is widely known that financial markets can become dangerously unstable, yet it is still unclear why. Numerous reasons have been proposed to explain it; these include debt accumulation, incorrect beliefs about the earnings process, limits to arbitrage, asset incompleteness, herding or momentum trading. Another possible explanation can be the hormones contained in our bodies, specifically basal testosterone and cortisol that may critically influence traders' financial decision making, particularly when participating in an environment as stressful and competitive as a modern financial market (Coates & Herbert, 2008). In this thesis we will investigate in particular the correlation of the hormones cortisol and testosterone, including their interaction, with the economically important individual traits of risk-taking and the willingness to compete. If there were enough evidence for a direct link between the physiological hormones and behavioral traits, it would be basically enough to take someone´s sample of saliva and indirectly infer how the person may behave, for example, in relation to risk. More generally, we aim to contribute to the literature on the biological underpinnings of important economic behaviors.

Willingness to compete is an important trait that has been shown to guide real world behavior, such as choosing career (Buser et al., 2014, 2017) It is generally established that men are, on average, more competitive than women and this fact can help to explain gender differences in economic outcomes (e.g. Niederle & Vesterlund, 2007, 2011). If women are less likely to compete, this not only reduces the number of women who enter tournaments, but also those who win tournaments, which relates to situations like university admissions, job interviews, asking for promotion and working in high-stakes environment. Risk traditionally plays an important role in almost every economic decision-making (e.g. Dohmen et al., 2011). Understanding individual risk attitudes is closely linked to the goal of understanding and predicting economic behavior. Apart from that, large number of research studies in experimental economics support a consensus that women are more risk averse than men (e.g. Charness & Gneezy 2011). The role of hormones in the determination of both risk-taking as well as in the willingness to compete, potentially explaining the observed gender gaps, has been however relatively under-explored.

Studies such as Eisenegger et al. (2016) or Geniole et al. (2016) have shown that basal testosterone levels correlate positively with psychometric measures such as the self-reported ability to win in competition. It is generally concluded that an increase in the level of this hormone encourages, while a decrease in level of this hormone discourages the decision to compete further. On the other hand, some competition designs have revealed no relationship

between basal testosterone and an individual´s decision to compete (e.g. Edwards et al., 2006). Support for the testosterone´s influence on human behavior generally stems from real-world sports competitions and rigged laboratory competitions.

Testosterone plays significant roles in biological development, is a central biological driver of gender differences, and has recently been shown to influence various economic decisions making (Nadler et al., 2017). It is usually taken as a performance enhancer among some financial professionals. Testosterone also plays an important role in social behavior. A Weber´s et al. (2012) interpretation of the existing evidence on the role of testosterone in social behavior is that the hormone enhances dominance behavior. Cortisol is a hormone that brings glucose and thus energy to the bloodstream and is mostly known to be released during the physiological response to physical or psychological stress, but also during a physical exercise and high arousal. Moreover, cortisol has been shown to affect risk preferences and to correlate with instability in financial markets (e.g., Cueva et al., 2015, Coates & Herbert, 2008, Kandasamy et al., 2014).

Apart from that, we are interested in the effect of their interaction based on the so-called dual-hormone hypothesis with respect to risk-preferences and competitiveness. The dual-hormone hypothesis posits that basal cortisol and testosterone have a joint effect on dominance and risk-taking, i.e. there is a positive association between testosterone and attitudes to risk, but only when cortisol level in an individual is low (e.g. Mehta & Josephs, 2010, Mehta et al., 2015).

Another point of our interest is how the effects are mediated by the 2D:4D ratio (the ratio between the length of the 2nd (index) finger and the 4th (ring) finger of a right hand) and the trait anxiety. The 2D:4D ratio is considered to reflect the exposure to testosterone *in utero* thus before common economic, social, and cultural factors could shape competitive behavior of the individual directly. It is supposed to have an influence on how testosterone works in adulthood (Manning & Taylor, 2001) and some studies show its relationship with economic behavior (e.g. Coates et al, 2009). The second investigated modulating factor is the trait anxiety that can be defined as a feeling of unease, worry, tension, and stress. It is useful to explain economic decisions with personality traits as individual differences in personality shape the constraints of individuals, and hence their choices (Borghans et al., 2008). Trait anxiety has been shown to play role in modulating the effects on economic behavior.

Hypotheses:

1. Basal testosterone levels correlate positively with the decision to compete.
2. Dual-hormone hypothesis - testosterone's effect on willingness to compete depends on cortisol.
3. Dual-hormone hypothesis for risk-taking.

Methodology:

We run a controlled lab experiment with a student subject pool to investigate our research questions. We analyze the data using standard econometrics measures in order to test our hypotheses. We primarily investigate the effect of basal testosterone on competitiveness and risk-taking with respect to basal cortisol. Above that, we also focus on the mediating role of 2D:4D ratio, and the trait anxiety. Furthermore, we analyze how testosterone affects the difference between women and men.

Design of the experiment

Before the subjects come for the experiment, they fill in an online questionnaire with a set for the measurement of the trait anxiety. At the beginning of the experiment, subjects are asked to answer on a set of questions of their personality scales called the Big Five personality traits (Costa & McCrae, 1992). Next, we use the same method to measure competitiveness as in Gneezy et al. (2016) based on Niederle & Vesterlund (2007). We conduct an experiment in which participants solve a real math tasks and are rewarded in the first two-minute round using a piece-rate scheme while in the second round using a tournament scheme. Then, in the competitive task, subjects chose *ex-ante* how they want to be compensated for their performance in the counting portion of this upcoming task. They do so by splitting 100 points between the tournament and the piece-rate compensation schemes. For each point invested in the piece-rate scheme, they earn 0.25 CZK per correct answer. For each point invested into the tournament compensation scheme, they earn 0.5 CZK per correct answer, but only if they have more correct answers in this task than another randomly selected participant in previous task, and receive nothing per each point invested in the tournament scheme if they answer fewer questions. In case of a tie, each point invested in the tournament account is rewarded according to the piece-rate scheme.

After this, we also conduct another task to measure risk preferences using a setting based on Dohmen et al. (2010). In this task, subjects are asked to repeatedly choose between a lottery, which is always kept the same at 240 CZK versus 0 CZK with 50% probability each, and a safe payment, which is gradually increasing from 0 CZK to 240 CZK in the steps of 20 CZK.

The 2D:4D ratio is the ratio between the length of the 2nd finger and the 4th finger of the subjects' right hand. The hands are scanned on the end of the experiment and then the ratio is calculated.

Expected Contribution:

The main aim of the thesis is to contribute to the growing body of studies focused on the role of hormones in the economic behavior, particularly in competitive behavior and risk-taking. We want to test on our subject pool the dual hormone hypothesis that higher level of basal testosterone implies more competitiveness and risk-taking, but only in subjects with low cortisol. We also analyze how 2D:4D ratio and trait anxiety influence the economic behaviors that has been, so far, mainly done in a sport´s context.

Outline:

1. Introduction
2. Theoretical background
3. Literature review
4. Methodology
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7. Conclusion

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Author **Supervisor**

1 Introduction

It is widely known that financial markets can become dangerously unstable, yet it is still unclear why. Numerous reasons have been proposed to explain it; these include debt accumulation, incorrect beliefs about the earnings process, limits to arbitrage, asset incompleteness, herding or momentum trading. Another possible explanation can be the hormones contained in our bodies, specifically basal testosterone and cortisol that may critically influence traders' financial decision making, particularly when participating in an environment as stressful and competitive as a modern financial market (Coates & Herbert, 2008). In this thesis, we will investigate in particular the effect of the hormones cortisol and testosterone, including their interaction, on the economically important individual traits of risk-taking and willingness to compete. If there were enough evidence for a direct link between the physiological hormones and behavioral traits, it would be basically enough to take someone´s sample of saliva, which can be easily collected, and indirectly infer how the person may behave, for example, in relation to risk. More generally, we aim to contribute to the literature on the biological underpinnings of important economic behaviors, namely willingness to compete and risk taking.

Willingness to compete is an important trait that has been shown to guide real world behavior, such as choosing career (Buser et al., 2014; 2017). It is generally established that men are, on average, more competitive than women and this fact can help to explain gender differences in economic outcomes (Niederle & Vesterlund, 2007, 2011). If women are less likely to compete, this not only reduces the number of women who enter tournaments, but also those who win tournaments, which relates to situations like university admissions, job interviews, asking for promotion and working in high-stakes environment. Risk traditionally plays an important role in almost every economic decision-making (Dohmen et al., 2011). For example, the analysis of portfolio models is based on strategies to differentiate risk according to investor attitude. In macroeconomics, we can consider unemployment, exchange and interest rates, political stability, imports and exports as examples of the unstable economic variables that influence the overall economy. Understanding individual risk

attitudes is closely linked to the goal of understanding and predicting economic behavior. These personal characteristics are recently considered to be tightly related to individual hormone levels.

We have already dealt with a similar topic in our previous work that was focused on the nature of gender differences in attitudes to risk (Sýkora, 2015). In line with a large number of research studies in experimental economics (Charness & Gneezy, 2011), we supported the consensus that men are more risk taking than women. Nevertheless, the role of hormones in the determination of both risk-taking as well as in the willingness to compete, potentially explaining the observed gender gaps, has been relatively under-explored. In this thesis, we also try to shed some light on why we can observe these gender differences, whether or not it is influenced by the hormones.

Studies such as Eisenegger et al. (2017) and Geniole et al. (2017) have shown that basal testosterone levels correlate positively with psychometric measures, e.g. the self-reported ability to win in competition. It is generally concluded that an increase in the level of this hormone encourages, while a decrease in level of this hormone discourages the decision to compete further. On the other hand, some competition designs have revealed no relationship between basal testosterone and an individual´s decision to compete (Edwards et al., 2006). Support for the testosterone´s influence on human behavior generally stems from real-world sports competitions and rigged laboratory competitions (Cueva et al., 2015; and Oliveira et al., 2009). The inconsistent results in the literature are an opportunity for further research. One possible explanation for that is the dual-hormone hypothesis as the interaction of the two investigated hormones.

We are interested in the dual-hormone hypothesis with respect to risk-preferences and competitiveness. The dual-hormone hypothesis posits that basal cortisol and testosterone have a joint effect on competitiveness and risk-taking, i.e. there is a positive association between testosterone and attitudes to compete and take risk, but only when cortisol level in an individual is low (Mehta & Josephs, 2010; and Mehta et al., 2015).

Another point of our interest is how the effects are mediated by the 2D:4D ratio (the ratio between the length of the 2nd index finger and the 4th ring finger of a right hand), the trait anxiety, and the Big Five personality traits, which have not yet been extensively examined in connection with the hormones. The 2D:4D ratio is considered to reflect the exposure to testosterone in utero thus before common economic, social, and cultural factors could shape competitive behavior of the individual directly. It is supposed to have an influence on how testosterone works in adulthood (Manning & Taylor, 2001) and some studies show its relationship with economic behavior (Coates et al, 2009). The next investigated modulating factor is the trait anxiety, a commonly used measure introduced by Spielberger et al. (1983). It is useful to explain economic decisions with personality traits as individual differences in personality shape the constraints of individuals, and hence their choices (Borghans et al., 2008). Trait anxiety has been shown to play role in modulating the effects on economic behavior, e.g. the impact of stress on competitive confidence (Goette et al., 2015).

The main contribution and novelty that we bring to the topic is the dual-hormone hypothesis as it has not been sufficiently analyzed and replicated so far. There is a certain consensus, how it should work, but the empirical support is rather ambiguous. Furthermore, even though most research on testosterone and behavior has been conducted on males, there is growing evidence that testosterone also plays a role in female social behavior. And unlike the others, we have a gender-balanced dataset, thus we can examine gender differences in the competitive and risk-taking behavior. Overall, we could collect valuable information from our laboratory experiment and subsequent analysis with a certain predictive value.

Our results surprisingly cannot confirm the hypothesis that higher levels of basal testosterone lead to increased willingness to compete as opposed to most of the recent literature. Moreover, higher levels of both investigated hormones decrease competitiveness and risk taking but only for women. We find no statistically significant support for cortisol and 2D:4D ratio effect on willingness to compete for men, but we find positive effect of the 2D:4D ratio for women. Our results further suggest that men with higher level of trait anxiety have lower willingness to compete.

We also find substantial gender differences in willingness to compete that corresponds to general research and confirms the consensus in the literature (Croson & Gneezy, 2009; and Niederle & Vesterlund, 2007). Our findings thus indirectly support the fact that men overtrade much more and generate larger price bubbles than women (Eckel & Füllbrunn, 2015). It can also help to explain why men hold a vast majority of trading jobs on financial markets. It further confirms finding of Buser et al. (2014) about labor markets. Some job entrance interviews are done in highly competitive environment that suits more to men who are more competitive, and thus there is a lower propensity of women applying for the job.

Based on our results, we cannot confirm the dual-hormone hypothesis for willingness to compete. Nevertheless, unlike the current studies on this topic (Bedgood et al., 2014; and Mehta & Josephs, 2010) we have a gender-balanced sample and can account for the effect of gender. On the other hand, we find significant support for the dual-hormone hypothesis for risk taking but only among women and with negative effect of testosterone on risk taking. The significant effect stays robust even after controlling for other influential variables. It may help to explain some ambiguous results in testosterone research on risk taking, because there are studies suggesting that cortisol antagonize the relation between testosterone and human behavior.

The thesis is structured as follows. Chapter 2 defines all the key terms and expressions that are necessary to understand the analysis. Chapter 3 summarizes already existing literature related to our topic. In Chapter 4 we describe laboratory experiments as an important part of experimental economics. Chapter 5 deals with the methodological procedure and our hypotheses. Chapter 6 presents design of the experiment and shows basic summary statistics of the data. In Chapter 7 we analyze our dataset in order to test the hypotheses and present the results. Chapter 8 discusses the results and suggests possible implications. Finally, Chapter 9 concludes the thesis and highlights the most important findings.

2 Theoretical background

Before we start with the actual topic of this work, it is necessary to set definitions of all key terms and expressions that are important to understand in detail and consequently to be able to properly understand our analysis and hypotheses. We explain them in the scope that fulfills the purpose of our thesis. As we work with the hormones, it is also important to know a necessary biological background of the topic. Then it can also help us in understanding how it can be used in economics.

2.1 Hormones

Hormones are chemical messengers that are released by glands and certain neurons in the brain to motivate both long term physical and neurological features and short term behavioral changes. They carry signals in the bloodstream that are important for the functioning of the body and affect many kinds of human behavior.

We are primarily interested in testosterone and cortisol which belong into the class of hormones called steroids. Other important classes of hormones are amines (that are represented e.g. by adrenalin and noradrenalin), peptides and proteins (e.g. oxytocin and leptin). Steroids are lipids cleaved from cholesterol by a series of enzymatic modifications, with the major sites of biosynthesis being the gonads and the adrenal cortex.

According to Coates et al., (2010), steroids constitute a particularly influential class of hormones because of their range of action. With receptors in almost every nucleated cell in the body, they affect growth, metabolism, immune function, mood, memory, cognition and behavior. Steroids are of special interest for the study of emotions and economic behavior because they help coordinate body and brain in archetypical situations, such as fight, flight, mating, feeding, search and struggle for status. As known from a sport environment, there is evidence that anabolic steroids are addictive in humans.

Steroid hormones also influence sexual differentiation at key stages in our development. Stroud et al. (2002) claim that women have only 5–10% of the circulating levels of testosterone of men, and they have not been exposed to the same organizing effects of prenatal androgens. Furthermore, Phoenix et al. (1959) found that neonatal castration of male rats causes them to develop behaviorally as females.

Hormone levels are not stable all the time and change during our lives (Dreher et al., 2007), with testosterone and oestrogen declining, and cortisol increasing; so young and old have markedly different endocrine profiles. It implies that age of the financial market participants also might play an important role in their decision making by changing the hormone levels.

2.1.1 Testosterone

Testosterone is part of a class of hormones called anabolic steroids, or androgens. It is mostly thought of as a primary male sex hormone, although women produce it too, but in a much lesser extent that causes one of the most important biological differences between women and men. A majority of testosterone is produced in the sex organs (testes in men and the ovaries in women) in the Leydig cells, with a small amount produced in the adrenal glands. It is regulated by the hypothalamic-pituitary-gonadal axis.

Testosterone has two pronounced effects on human body – anabolic and androgenic. Anabolic effects promote development of the musculature and strength, increased bone growth and density, and stimulation of linear growth and bone maturation. Androgenic effects, as a consequent secretion of testosterone, include maturation of the reproductive organs, particularly the penis and the formation of the scrotum in the fetus. They also include a development of secondary sexual characteristics (usually at puberty) such as a deepening of the voice, growth of facial hair and axillary hair (Coates et al., 2010).

Testosterone regulates fertility, fat distribution, and red blood cell production. It is believed to play a key role in modulating physiological and behavioral processes critical to survival and reproduction (Geniole et al., 2017). Testosterone also plays

significant roles in biological development and is a central biological driver of gender differences. Notably, testosterone concentrations are not static, but rather vary cyclically and in response to challenge fluctuate rapidly within the context of social interactions according to victory or defeat (Nadler et al., 2017). Since testosterone levels gradually decrease as men age, synthetic testosterone is sometimes prescribed to older men to counteract this deficiency.

Testosterone is known to influence brain development and reproductive physiology, but also plays an important role in social behavior. A Wibral´s et al. (2012) interpretation of the existing evidence on the role of testosterone in social behavior is that the hormone enhances dominance behavior, i.e., behavior intended to gain high social status, which in humans can be associated with increased aggression, sexual function and mood.

2.1.2 Cortisol

Cortisol is a steroid hormone; one of the glucocorticoids, produced in humans by the cortex of the adrenal glands synthesized from cholesterol and is regulated by the hypothalamic–pituitary–adrenal axis. Cortisol is a hormone that brings glucose and thus energy to the bloodstream. Almost every cell contains receptors for cortisol, therefore it regulates a wide range of processes and affects many different functions in the human body depending on which sort of cells it is acting upon. Cortisol can help control blood sugar levels, regulate diverse processes such as metabolism, cardiovascular biology, and immune function, help reduce inflammation, and assist with memory formulation. It has a controlling effect on salt and water balance and helps control blood pressure. It also decreases bone formation. In women, cortisol also supports the developing fetus during a pregnancy (Coates et al., 2010; and Mehta & Josephs, 2010).

Cortisol plays a central role in modulation of the physiological and behavioral response to a physical challenge or psychological stressor and thus is considered to be one of the main stress hormones. It is also released in response to low blood-glucose concentration, during a physical exercise, waking up, and high arousal. Cortisol is particularly sensitive to situations of uncontrollability, novelty, uncertainty, or threat.

When in a novel environment or a state of uncertainty, people usually do not know what to expect, so rising levels of cortisol accompany a preparatory stress response. Its wide-ranging effects include altering mood, memory, and behavioral response to threatening circumstances (Coates & Herbert, 2008; and Kandasamy et al., 2014).

Acute and chronic exposures to cortisol can have very different, and in many cases opposite, effects. Acute increases in cortisol promote fear, physical arousal, learning, motivated behavior, and sensation seeking (Cueva et al., 2015). On the other hand, when the acute responses are overused or inefficiently managed, allostatic load may occur. Allostatic load refers to the price which our body has to pay for being forced to adapt to adverse psychosocial or physical situations. Repeated stress leads our body over time to wear out or become exhausted that can accelerate various disease processes (cancer, asthma, or cold). All together, it implies a short-term adaptation and a potential long-term damage associated with stress hormones such as cortisol. Another risk factor connected with stress is early childhood experiences of abuse and neglect that increase allostatic load later in life and lead individuals into social isolation, hostility, depression, and conditions like extreme obesity (McEwen, 2000, 2004).

Blood levels of cortisol vary dramatically, but generally are high in the morning when we wake up, and then fall throughout the day. We can also observe significantly larger salivary cortisol response in healthy adult men compared to women following short-term stress. There were also found potential meal related salivary cortisol increases, especially in meals containing proteins (Kudielka et al., 2009; and Lovallo et al., 2006).

2.2 Willingness to compete

Smither & Houston (1992) define generally competitiveness as the desire to win in interpersonal situations. The interpersonal nature of the construct implies that competitiveness is inextricably tied to an individual´s actual or perceived social environment. Highly competitive people like competition and get satisfaction from competing against others.

Our understanding of competitiveness for the purpose of the analysis is based on the design introduced by Niederle & Vesterlund (2007). They work with the definition that competitiveness is a selection into a competitive environment, i.e. whether an individual wants to enter tournament or not. They used a real math task in their experiment that is not exciting, but rather requires participants to be very careful not to make simple mistakes. At first, subjects perform the math task under non-competitive piece rate compensation and subsequently undergo a competitive tournament. While subjects are informed of their absolute performance after each task, they do not receive any feedback on their relative performance. Then they choose which of the two compensation schemes they want to receive for their performance of the next math task that is actually the measure of competitiveness. It is an environment that is as close as possible to the tournament entry decision, without involving an actual tournament performance.

Niederle & Vesterlund (2007) mainly focus on the gender differences in preferences for competition, i.e. whether women shy away from competition. They further deal with the possible explanations of differences between women and men and how such differences impact economic outcomes. They also suggest that the willingness to compete is closely linked to overconfidence. Unlike them, we primarily focus on the role of hormones in the competitive behavior. There may be other methods of measuring competitiveness, which we will not discuss here, because they are not important for our research.

2.3 Risk taking

Hillson & Murray-webster (2004) define risk attitude as a chosen state of mind with regard to those uncertainties that could have a positive or negative effect on objectives. We can divide risk attitudes according to the expected utility theory into three basic categories and that is risk aversion, risk neutrality, and risk seeking. They describe a risk averse person, from a psychological perspective, as a person who feels uncomfortable with uncertainty, has a low tolerance for ambiguity, and seeks security and resolution in the face of risk. On the other hand, person who is risk seeking tends to be adaptable, resourceful, enjoying life, and not afraid to take action.

Risk taking is central to human activity and is inescapable. We take risks in situations such as playing a sport, entering a personal relationship, or choosing a career. In modern society, hyper-risky behaviors can create numerous individual costs and societal burdens, such as the spread of infections, dangerous driving resulting in injury or death, and substance abuse. In the financial sector, the appetite for risk taking among those working on the world's trading floors affects the stability of financial markets, the growth of the economy, and consequently the well-being of the wider population (Kandasamy et al., 2014; and Steinberg, 2008).

2.4 2D:4D ratio

Second-to-fourth digit (2D:4D) ratio is the ratio between the length of the 2nd (index) finger and the 4th (ring) finger of the same hand. It is measured from basal crease to the finger tip. A longer index finger results in a ratio higher than 1, while a longer ring finger results in a ratio lower than 1. The 2D:4D ratio is considered to reflect the early exposure to testosterone in utero with lower 2D:4D ratio (i.e. a shorter index finger in comparison with the ring finger) indicating a higher prenatal testosterone exposure (Bosch-Domènech et al., 2014; Manning & Taylor, 2001; Neave et al., 2003).

According to Coates et al. (2009), evidence of a connection between digit ratios and prenatal androgens comes from the observation that 2D:4D is sexually dimorphic, with male ratios being, on average, shorter than those of females. This dimorphism emerges in the first trimester of development and is established in children by the age of 2 years. Bosch-Domènech et al. (2013) further claim that the ratio varies by ethnicity and the effect is strongest in the right hand.

There is an evidence that the 2D : 4D ratio affects some cognitive skills such as musical ability, spatial perception and cognition, verbal and numerical intelligence, and memory recall (Brañas-Garza & Rustichini, 2011). Low 2D:4D ratio is usually associated with predisposition towards autism, left-hand preference, male homosexuality and male membership of a symphony orchestra (Manning & Taylor, 2001; Manning, 2002).

2.5 Trait anxiety

The trait anxiety inventory is a commonly used self-reported measure of anxiety introduced by Spielberger et al. (1983). Anxiety can be defined as a feeling of fear, unease, discomfort, worry, or tension. It can be a reaction to stress, or it can occur in people who are unable to identify significant stressors in their life. It is also used in clinical settings to diagnose anxiety and to distinguish it from depressive syndromes. Trait anxiety has been shown to play role in modulating the effects on economic behavior, for instance, the impact of stress on competitive confidence (Goette et al., 2015).

2.6 Big Five personality traits

The Big Five personality traits are five broad domains which define human personality and account for individual differences. They are measured by NEO Personality Inventory in a set of questions first introduced by Costa & McCrae (1992) as a revision of the original version to facilitate a comprehensive and detailed assessment of normal adult personality. It provides a systematic assessment of emotional, interpersonal, experiential, attitudinal, and motivational styles which means a detailed personality description that can be a valuable resource for a variety of researchers. The five personality traits are openness, conscientiousness, extraversion, agreeableness, and neuroticism. In the box below (Figure 1), we can see closer characteristics of these personality traits.

Figure 1: Description of the Big Five personality traits

Openness	▪ active seeking and appreciation of experiences for their own sake ▪ being curious, original, imaginative, intellectual, creative, and open to new ideas
Conscientiousness	▪ degree of organization, persistence, control and motivation in goal directed behaviour ▪ being reliable, organized, systematic, punctual, prompt, and achievement-oriented
Extraversion	▪ quantity and intensity of energy directed outwards into the social world ▪ being outgoing, talkative, assertive, excitable, and enjoying social situations
Agreeableness	▪ tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others ▪ being affable, tolerant, trusting, kind, cooperative, and compassionate
Neuroticism	▪ relates to individual's emotional stability and degree of negative emotions ▪ being anxious, irritable, temperamental, and moody

Source: Sýkora, Z. (2015). On the Nature of Gender Differences in Attitudes to Risk. *Bachelor Thesis. Charles University in Prague, Faculty of Social Sciences, Institute of Economic Studies*, p. 34

3 Literature review

In this chapter, we will have a closer look on the already existing literature related to our topic. Researchers have been dealing with human behavior such as willingness to compete and risk-taking for quite a long time. We primarily focus on studies that explored individual´s testosterone and cortisol levels or their proxies. With a modern technology and laboratory facilities, hormone research in experimental economics has gained on popularity in last decades. We further analyze studies examining the interaction of the two investigated hormones (dual-hormone hypothesis) and also gender differences in competitiveness and risk preferences.

3.1 The effect of testosterone on human behavior

Many researchers have studied the effect of testosterone on human behavior and we will cover the most crucial ones. Some experimenters use a direct administration of testosterone, others observe the correlation or use meta-analysis. Furthermore, we analyze only studies based on incentivized competitive and risk-taking experiments and data from real world conditions, especially from trading and sport context. We argue that these studies provide more robust findings compared to other methods like questionnaires.

3.1.1 Willingness to compete

Studies such as Eisenegger et al. (2017) and Zilioli & Watson (2014) have shown that basal testosterone levels correlate positively with psychometric measures, for example, the self-reported ability to win in competition. The importance of testosterone in competitive interactions in various situations has been demonstrated by many researchers. Support for the testosterone´s influence on human behavior mainly stems from real-world sports competitions and rigged laboratory competitions (Oliveira et al., 2009). It is generally concluded that an increase in the level of this

hormone encourages, while a decrease in level of this hormone discourages the decision to compete further (Mazur & Booth, 1998). Moreover, Eisenegger et al. (2017) found that individuals who had higher basal testosterone levels were more likely to decide to compete even when controlled for other important factors.

3.1.1.1 Animal research

The effects of testosterone on competitiveness were originally found at animals, particularly in research of Mazur (1976; 1985) involving male rhesus monkeys where fluctuations in testosterone concentrations were dependent on the outcome of competitions, increasing after victories and decreasing after defeats, that helps to explain a social hierarchy in animals. Mazur & Lamb (1980) were the first to extend these findings to humans. Although there is some evidence that testosterone enhances competitive performance in animals, the evidence in humans is still mixed.

Consistent with the animal studies, there are human studies indicating that high levels of basal testosterone serve as a biological marker for an individual's motivation to gain social status and that testosterone changes after a status loss. Additionally, higher levels of testosterone are related to greater social dominance and confidence in individual´s performance (Bedgood et al., 2014; and Mehta & Josephs, 2006). Interestingly, according to Giammanco et al. (2005), athletes who illegally used anabolic steroids were largely observed to have behavioral changes such as an increase in aggressiveness or changes in mood.

3.1.1.2 Sport

There is a hypothesis that high testosterone individuals are motivated to gain high status (good performance in individual competition), whereas low testosterone individuals are motivated to cooperate with others (good performance in intergroup competition). It was supported in the study of Mehta et al. (2009). They found that testosterone was positively related to performance in individual competition and negatively related to performance in intergroup competition. The finding can be observed in a sport context as there are either individual or team sports.

Many studies use athletes of various individual sport disciplines as the experimental model. For example, male college tennis players experienced a rise in saliva testosterone concentrations after a decisive victory compared to a defeat. Similar apply to male university wrestlers where winners had elevated post-competition testosterone concentrations compared to losers (Mazur & Lamb, 1980). Moreover, there is also evidence that testosterone levels are higher in chess tournament winners, and among sport supporters, even though they are not taking part in the competitions. Bernhardt et al. (1998) took testosterone samples from fans during a football World Cup match in 1994 in which Brazil defeated Italy. Both sets of fans went into the game with elevated testosterone, but afterwards the testosterone of Brazilian fans rose while the testosterone of Italians fans fell. The results of sporting events and associated changes in the fans testosterone levels can help to explain why stock market returns respond to results of major sporting events.

3.1.1.3 Winner-loser effect

Close connection to sport has a so called winner-loser effect that was firstly formally introduced by Booth et al. (1989). As we already know, testosterone rises after victories and drops after defeats in competitive interactions and thus the victory increases the probability of success in the future contests, which obviously means a big advantage. Many studies have dealt with the winner-loser effect and found consistent results (Mazur & Booth, 1998; and Zilioli & Watson, 2014).

Coates et al. (2010) examined the relevance of the winner-loser effect on the real financial market by looking for evidence that traders experience an increase in testosterone when they enjoy an above-average win in the market. They discovered that these traders had significantly higher testosterone levels on days when they made an above average profit.

3.1.1.4 Auctions

In the experimental asset market, it has been shown that testosterone causes significantly higher and longer-lasting asset overpricing and overbidding strategies in auctions. And what more, under real working conditions, traders have been found to

make significantly higher profits on days when their morning testosterone levels were above their daily average (Coates & Herbert, 2008; and Van Den Bos et al., 2013).

Testosterone is supposedly taken as a performance-enhancer among some financial professionals, and so Nadler et al. (2017) used a direct administration of testosterone for the analysis of asset traders. They found that exogenously increasing testosterone in traders generates higher bidding prices and causes price increases for an asset with a universally known fundamental value, leading to price bubbles and crashes.

On the other hand, some competition designs such as first-price auctions have revealed no relationship between basal testosterone and an individual´s willingness to compete (Edwards et al., 2006; and Schipper, 2015), which can be, for example, explained by the influence of other hormones.

3.1.2 Risk taking

It is generally supposed that testosterone plays a substantial role in individual´s risk taking. Many studies including Apicella et al. (2008); Eisenegger et al. (2017); and Steinberg (2008) have found that higher levels of basal testosterone are positively related to risk taking, especially for males. In addition, Apicella et al. (2014) claim that men whose testosterone concentrations increased in response to a competition were less risk averse than men whose testosterone concentrations dropped.

Several studies also found that risk taking in investment decisions is positively correlated with salivary testosterone level that can have a destabilizing role in financial markets through different individual´s risk attitudes (Apicella et al., 2008). In addition to that, Cueva et al. (2015) found similar results also by direct administrating of testosterone in incentivized risk taking experiment.

3.2 The effect of cortisol

Cortisol has mainly been studied in connection with stress so far and not that much separately with its effect on competitiveness and risk taking. Nevertheless, there is a sufficient evidence that high levels of cortisol are correlated to risk aversion and uncertainty as opposed to testosterone, including among traders (Coates et al., 2010; and Van Honk et al., 2003). On the other hand, there are inconsistent findings about the correlation of basal cortisol and willingness to compete (Borráz-León et al., 2017; and Schipper, 2015).

3.2.1 Stress

In most studies, stress response is measured by cortisol levels as it was lately documented that salivary cortisol is a useful biomarker in the stress research. Nevertheless, the validity has been questioned by Hellhammer et al. (2009) as they claim that psychobiological mechanisms can only indirectly be assessed by salivary cortisol measures. There is evidence that stress reduces willingness to compete and it is more significant for females (Cahlíková et al., 2016; Lovallo et al., 2006). In addition, Lovallo et al. (2006) also find that caffeine further increases cortisol levels during periods of stress. Chemin et al. (2013) indirectly show that poverty leads to stress by finding correlations between annual levels of rainfalls and levels of the stress hormone cortisol among poor farmers in Kenya. And what is more, Giurgiuca et al. (2017) claim that patients with a history of suicidal ideation have significantly higher total cortisol levels than patients with no history of suicidal behavior.

3.2.2 Direct administration

Interestingly, Riis-Vestergaard et al. (2018) use a direct administration of the stress hormone cortisol in a laboratory study by pharmacologically increasing levels of the hormone. They focused mainly on the effect of cortisol on inter-temporal discounting but also on economic choice in general. Their results suggest that higher levels of cortisol increase participants' impatience thus increase temporal discounting, which means a decrease in the subjective value of a reward when it is delayed. Furthermore,

Kandasamy et al. (2014) found that elevated cortisol levels caused participants to become more risk-averse and that risk preferences are highly dynamic.

3.2.3 Financial markets

Cortisol has not been investigated at asset traders as much as testosterone, but mainly in relation to risk preferences. So from the brief evidence (Coates & Herbert, 2008; and Cueva et al., 2015), we can deduce that significant elevations of cortisol levels have been associated with trading activity, mispricing, and financial risk preferences. Trader´s cortisol also rises with increased variance of trading results (profits) and increased volatility of the markets. It may imply that cortisol can predict instability in financial markets. Coates et al. (2010) further suggest that the irrational exuberance and pessimism observed during market bubbles and crashes are mediated by cortisol as well. Overall, cortisol may critically influence traders' financial decision making and affect the ability to engage in rational choice, similarly to testosterone.

3.2.4 Sport

Furthermore, Edwards et al. (2006) found that salivary cortisol levels in women professional handball and volleyball players increase during competition. In addition, cortisol as well as testosterone in women rugby players increase during one day before a match and continue to rise during the match in both victory and defeat.

3.3 Dual-hormone hypothesis

Most researches have investigated testosterone and cortisol independently, but recently, there is a tendency to observe the effect of both hormones, particularly their interaction and consequently to explain the inconsistencies in results either in willingness to compete or risk taking of the studies dealing just with one hormone, especially testosterone. The dual-hormone hypothesis posits that basal cortisol and testosterone have a joint effect on dominance and risk-taking, i.e. there is a positive association between testosterone and attitudes to risk, but only when a cortisol level in an individual is low (Mehta & Josephs, 2010; and Mehta et al., 2015).

Research by Bedgood et al. (2014) also supports the dual-hormone hypothesis as they found that stressful situations lead to a decrease in testosterone and conversely participants with lower basal cortisol recorded a higher increase in testosterone compared to others.

Although it has been speculated that interactions between these two hormones might be an important mechanism for social behavior, this approach has received negligible attention in empirical research so far.

3.4 Gender differences

As we already know, there is one important biological difference between women and men. On average, men have significantly higher levels of basal testosterone by nature. Studies including Sapienza et al. (2009) and Brañas-Garza & Rustichini (2011) support that the gender differences in behavior such as willingness to compete and risk taking may be driven by the hormone testosterone.

Large number of research studies in experimental economics support a consensus that women are more risk averse than men (Croson & Gneezy, 2009; and Charness & Gneezy, 2011). Similar applies to willingness to compete as there were found significant gender differences which can be interpreted as that women shy away from competition and men embrace it (Croson & Gneezy, 2009; Niederle & Vesterlund, 2007, 2011).

3.4.1 Labor market

There is growing evidence that substantial share of gender differences in education choices, career decisions, and labor market outcomes can be explained by gender differences in willingness to compete. In addition, the gender gap increases steadily with the ability of students and is almost zero among the lowest-ability students (Buser et al., 2014, 2017).

Competitive workplaces can significantly decrease the propensity of women that apply for a job compared to men. It was supported by Flory et al. (2010) who

conducted large scale natural field experiment on job-entry decisions. They also found that women are more likely to be deterred from competitive work environments if there are good outside options. In addition, gender differences in preferences for competition were partly found to be dependent on the nature of the task performed and on the form of the local labor market. Nevertheless, their experiment has several shortcomings such as specific type of the job in the experiment or exploring job applications rather than final acceptance of the job.

3.4.2 Financial market

Several papers show that men compared to women exhibit greater overconfidence (Lundeberg et al., 1994), overtrade and take more financial risk (Charness & Gneezy, 2011), generate larger price bubbles in experimental markets (Eckel & Füllbrunn, 2015), and hold a vast majority of trading jobs on financial markets (Nadler et al., 2017). There is also evidence that on average women bid higher and earn lower profits than men in first-price auctions (Pearson & Schipper, 2013). On the other hand, there are also many studies that find no significant gender differences in attitudes to risk or willingness to compete regarding financial market context (Crosetto & Filippin, 2013; Crosetto et al., 2014; and Deaves et al., 2009).

3.5 2D:4D ratio

Not surprisingly, results of the 2D:4D ratio´s effect on willingness to compete and risk taking are similar to those of testosterone, because the ratio reflects a prenatal exposure to testosterone (Bosch-Domènech et al., 2014; Manning & Taylor, 2001; Neave et al., 2003).

Low 2D:4D ratio is usually associated with increased risk taking, perceived dominance, better physical reflexes, and higher scores in abstract reasoning ability. Additionally, lower traders' 2D:4D ratio has been also found to correlate with higher profitability, career longevity, effectiveness in processing information, and long-term success in a high-frequency market (Brañas-Garza & Rustichini, 2011; Coates et al., 2009, 2010; Cueva et al., 2015; and Neave et al., 2003).

Besides other studies, Manning & Taylor (2001) reported that the ratio predicts willingness to compete in sports events (e.g. football). Athletes with low 2D:4D ratios had higher attainment in a variety of sports and also higher mental rotation scores. For example, athletes who represented their country had even lower ratios than those who did not, and there was also a significant negative association between 2D:4D ratio and number of international appearances after removing the effect of a country.

Nevertheless, studies such as Pearson & Schipper (2009) show a null result for the correlation between the 2D:4D ratio and competitive bidding and profits in first-price auctions. In addition, Brañas-Garza & Rustichini (2011) found no significant effect of the ratio on competitiveness for females.

4 Laboratory experiments

Laboratory experiments are one of the most commonly used research designs and are now also an important part of experimental economics. Most of the sciences test their theories in a controlled experiment, nevertheless, with the exception of psychology; social sciences have been a little slower in adopting controlled laboratory experiments in comparison to the natural sciences such as physics, chemistry, and biology. Despite the view that economics is purely observational or theoretical, there is recently a trend in economics in a growth of experiments as a valid and accepted methodology. For instance, the importance of experimental economics can be demonstrated by awarding Daniel Kahneman (experimental psychologist) and Vernon Smith (experimental economist) the 2002 Nobel Prize in Economics, and recently Richard H. Thaler (behavioral economist) was awarded the 2017 Nobel Prize in Economics. In addition, results from laboratory experiments are being published in the leading economics journals and many top departments have experimental laboratories now. Experimental economics is the application of experimental methods to study economic questions of how markets work and how economic agents interact. While the majority of laboratory experiments simulate markets and auctions, experimental economics methodology is also used to study and understand human behavior more widely (Friedman & Cassar, 2004).

4.1 Laboratory vs field experiments

Similarly to theoretical models, experiments are simplifications of the world. Experiments typically begin with a hypothesis which is a theory or explanation made on the basis of limited evidence as a starting point for further investigation. There are mostly two types of experiments in economics and i.e. laboratory and field experiments. Both of these approaches have some advantages and disadvantages when we compare them to each other.

4.1.1 Laboratory experiments

Laboratory experiments use a standardized procedure and are conducted in a highly controlled environment of a laboratory and therefore accurate measurements are possible. The controlled variation of factors allows scientists to measure the effect of independent variable on dependent variable, thus to be able to draw causal inferences. It can then help to predict the future behavior of the dependent variable. Controlled conditions also enable researchers to control and eliminate the effects of extraneous variables. Extraneous variables are factors that might be confounding and are not of interest for researchers, but they might interfere with the results of the experiment.

The laboratory provides a unique environment and ceteris paribus observations of individual economic agents, which are otherwise very difficult or even impossible to create in the field or find in naturally occurring situations. On the other hand, the environment is usually very artificial and manipulated by the researches, so when the laboratory experiment is not correctly designed, it might not be easily generalized to the real world. Moreover, there may be a sample selection bias as experiment´s participants consist mostly of students that is considered to be an unrepresentative sample.

4.1.2 Field experiments

Field experiments are conducted in a casual environment of the participants and are represented by more realistic conditions. There are several types of field experiments such as laboratory in the field, framed field, and natural field experiments that differ in the level of control and in the content. The experimenters still manipulates the independent variables but in a real-life setting. It is very difficult to extract the particular effect of interest from other simultaneously functioning effects, so there is less control over extraneous variables that might bias the results. This makes it more complicated for other researchers to replicate the study under exactly the same conditions. Field experiments provide a bridge between laboratory experiments and naturally-occurring data.

4.1.3 Comparison

Both methods are commonly used in the experimental economics and of course both have their advantages and disadvantages. Field experiment has higher ecological validity than a laboratory experiment, because behavior in a field experiment is more likely to reflect real life and its natural setting. There is also less likelihood of demand characteristics affecting the results, as participants may not be aware that they are studied. Conversely, laboratory experiments have higher control compared to field experiments where the extraneous variables are more likely to distort the findings. So it is much easier to replicate a laboratory experiment, because standardized procedures are applied. It also allows for better control of extraneous and independent variables. The laboratory and field experiments data represent a trade-off between internal and external validity of findings (see details below). Laboratory and field experiments both add special and complementary view of our understanding of economic behavior.

4.1.4 Other methods

There are also other methods used for the research such as the comparative method that involves comparing and looking for correlations in two or more similar societies or groups, which are similar in some respects but varied in others. Charness et al. (2013) introduced extra-laboratory experiments, which are generally closer to the classic laboratory experiments relative to field experiments, but are conducted in a non-standard manner. For instance, their experiments are not conducted on the student subject pool.

4.2 Validity

Validity in term of empirical economics is generally engaged with the fact whether a particular result or inference of our observations represents an adequate reflection of the truth state. In order to be sure that the outcome of experiment is valid it is necessary to properly design its structure. Regarding the validity of the experiment, we should distinguish two terms, i.e. internal and external validity.

4.2.1 Internal validity

Loewenstein (1999) state that “the internal validity of an experiment refers to the ability to draw confident causal conclusions from one´s research” or similarly Roe & Just (2009) define internal validity as “the ability of a researcher to argue that observed correlations are causal.” It also means in the internal validity context that the observed differences on the dependent variable are caused directly by changing independent variable and not by any other factor. The level of internal validity depends on the number of plausible alternative explanations for the results, which is mainly determined by the design and structure of the experiment.

Laboratory experiments have a high degree of control over the environment and extraneous variables, so they also have higher internal validity. Nevertheless, it can be greatly reduced by demand characteristics, which may help participants to guess the aim of the experiment. If they are aware of specific aspects of the experiment, it is possible that they will behave in such a way that they think they are expected to do so. Correlation studies generally have lower internal validity than experimental studies.

4.2.2 External validity

External validity can be defined according to Johnson & Christensen (2014) as “the extent to which the results of a study can be generalized to and across populations, settings, and times.” In other words, external validity is the ability to generalize results and findings of an experiment from laboratory to non-laboratory conditions (usually real world). A potential problem with the external validity is the behavioral bias of an experiment that might arise once the recruited subjects behave in the different way than they would under the real life setting. External validity is very important for studies that aim to inform policy.

The level of external validity is usually assumed to be higher in field than in laboratory experiments. External validity might be significantly lowered at the laboratory experiments due to the fact that experimenters are mostly forced to make the research more tractable by higher abstraction and simplification of the experiment

that increases the internal validity. Furthermore, Roe & Just (2009) claim that choosing between laboratory and field experiments data, usually requires a trade-off between the pursuit of internal and external validity.

4.3 Replicability

Due to the experimenter's high levels of control resulting in high level of internal validity, laboratory research procedures can be relatively easily repeated so that the reliability of results could be checked, whether through reanalyzing original data or by creating new data. Nevertheless, the replicability of scientific findings has been recently called into question. Camerer et al. (2016) examined how well laboratory experiments in economics can be replicated. They did so by replicating 18 studies published in the top American economic journals between 2011 and 2014. They found a significant effect in the same direction as the original study for 11 replications and moreover the reproducibility to be negatively correlated with the original p-value and positively correlated with the sample size. Replication of experiments seems to be generally successful, but there is still room for improvement (Zwaan et al., 2017).

4.4 Incentives

Laboratory experiments in most cases use cash to motivate subjects, in order to simulate real-world incentives. Experimental economists use financial incentives because they view them as necessary to ensure the validity of the experiments and also to ensure that participants will act normally. It makes subjects more responsive and may reduce variability in how experiments are done across different researchers and therefore it improves replicability. It is critical for theory testing that the participants actually face the payoffs assumed by the theory (Croson, 2005).

Laboratory experiments are also incentive compatible. It means that every participant can achieve the best outcome just by acting according to her true preferences and thereby it should better predict real life behavior.

4.5 Advantages

To sum up this chapter, laboratory experiments have several benefits for experimental economics. Laboratory provides a unique environment for tightly controlled variation of the experimental conditions, which is very hard or even impossible to create in the field or find in naturally occurring situations. Data collected in experiments are used to estimate effect size, test the validity of economic theories, and illuminate market mechanisms. Controlled conditions also allow eliminating the effects of extraneous variables and it is possible to establish cause and effect relationships between variables. There has been a lot of excitement recently about the applicability of experimental economics to solve complicated problems of market regulations (Guala & Mittone, 2005).

5 Methodology

The proper methodology is important for the validity of our results, and so in this chapter, we further explain all components of the methodological procedure and finally formulate our hypotheses. Most of the studies and methodologies are based on Niederle & Vesterlund (2007) who are the basic pillar in the topic.

5.1 Hypotheses

We primarily investigate the effect of basal testosterone on competitiveness and risk-taking with respect to basal cortisol. Our econometric analysis applied on the hypotheses is based on the data and experiment described in detail in the next chapter. We set the following hypotheses based on the already existing facts and literature:

5.1.1 Basal testosterone levels correlate positively with the decision to compete

The first basic hypothesis is whether the basal testosterone levels correlate positively with the decision to compete. It is very straightforward and easy to examine. Furthermore, the same effect should apply to basal testosterone and risk-taking as found by Apicella et al. (2008).

Assumption:

Based on the literature, we know that testosterone should affect competitiveness in a way that higher levels of testosterone increase individual´s willingness to compete (Eisenegger et al., 2017; and Geniole et al., 2017). Generally speaking, alpha males with high levels of testosterone are considered to have dominant position in the society and to be highly competitive.

Expectation:

In the regression where willingness to compete is the dependent variable, we would expect positive and statistical significant coefficient at the explanatory variable testosterone. It should also hold after adding other explanatory variables like gender and baseline cortisol to check robustness of the result. The same about the coefficients should apply to risk taking.

5.1.2 Dual-hormone hypothesis - testosterone's effect on willingness to compete depends on cortisol

Next key hypothesis is the dual-hormone hypothesis that testosterone´s effect on willingness to compete depends also on cortisol. So far, the effect of the hormones has been mostly studied separately. Traditional theories propose that testosterone and cortisol should influence behavior independently of each other (Mazur & Booth, 1998), but empirical support for these theories has been rather inconsistent.

According to the dual-hormone hypothesis, testosterone should be associated with aggression only for individuals with low cortisol (Popma et al., 2007). It seems plausible that the dual-hormone hypothesis may extend beyond these measures to competitiveness as well.

Nevertheless, there are also several studies that do not support the hypothesis (Denson et al., 2012; and Welker et al., 2014) or find non-significant basal testosterone and basal cortisol interactions on measures of aggression and dominance (Mazur & Booth, 2014).

Assumption

The dual-hormone hypothesis posits that basal cortisol and testosterone have a joint effect on dominance and competitiveness, i.e. there is a positive association between testosterone and willingness to compete, but only when individual´s cortisol concentrations are low (Casto & Edwards, 2016; and Mehta & Josephs, 2010). On the other hand, when cortisol concentrations are high, the model predicts that

testosterone's impact on status-seeking behaviors should be blocked or inhibited (Mehta & Prasad, 2015). It can possibly have psychological explanation through cortisol associations with stress and social avoidance.

Research on the dual-hormone hypothesis is still in its early stages, but the discoveries that have already emerged are expected to have practical applications. For instance, it has been found by Mehta et al. (2015a) that an increase in testosterone combined with a decrease in cortisol is associated with strong earnings in the laboratory experiment regarding face-to-face competitive negotiation, whereas an increase in both testosterone and cortisol is associated with weak earnings.

Expectation

We want to test on our subject pool the dual-hormone hypothesis that higher level of basal testosterone implies more competitiveness, but only in subjects with low cortisol levels. For our analysis, we use an Ordinary Least Squares regression common in experimental economics. We enter willingness to compete as the dependent variable and the remaining variables as predictors including basal testosterone and basal cortisol interaction.

The interaction term indicates that the relationship between testosterone levels and willingness to compete depends on cortisol levels. Thus, a statistically significant interaction between testosterone and cortisol would provide robust evidence in support of the dual-hormone hypothesis.

It addition, we expect a positive coefficient at testosterone and negative coefficient at interaction variables, because testosterone is expected to be positively related to competitive behavior only among individuals with low cortisol levels.

5.1.3 Dual-hormone hypothesis - testosterone's effect on risk-taking depends on cortisol

The dual-hormone hypothesis for risk-taking is almost equivalent to the previous hypothesis. Recent theories propose that testosterone should be positively associated with risk-taking regardless of cortisol concentrations, but empirical support is mixed

(Apicella et al., 2008; and Schipper, 2015). Building on the dual-hormone hypothesis, current research tests whether testosterone's role in risk-taking depends on cortisol. It is beneficial to analyze the dual-hormone hypothesis from the risk-taking perspective as risk preferences are an important part of our everyday lives.

Assumption

The dual-hormone hypothesis posits that basal cortisol and basal testosterone have a joint effect on risk-taking, i.e. there is a positive association between basal testosterone and attitude to risk only when individual´s cortisol level is low, but not among individuals with high cortisol levels (Mehta & Josephs, 2010; and Mehta et al., 2015b).

Expectation

The expectation is the same as in the previous hypothesis with only one exception that is the dependent variable, now it is a willingness to take risk. Otherwise the statistical approach will be the same.

5.1.4 Gender differences

In addition to these hypotheses, it is also interesting to examine the differences between women and men according to willingness to compete and risk-taking. Of course, we also want to observe how the dual-hormone hypotheses differ across gender.

As men generally have on average higher concentrations of testosterone than women, the majority of the testosterone-oriented literature has focused on men (Mehta & Josephs, 2010; and Popma et al., 2007). Moreover, there is a widespread consensus that women are less prone to compete and take risk (Croson & Gneezy, 2009; and Niederle & Vesterlund, 2007). Men may be more susceptible to this hormonal effect than women due to their higher testosterone levels.

Expectation

There are biological gender differences in the levels of the hormones especially in testosterone, so if there will be statistical significant results supporting the effect of these hormones, we should also expect gender differences in willingness to compete and risk taking.

5.2 Evaluation of hormonal methodology

There is recently a trend in using hormones to test their effect on human behavior in experimental economics. Nevertheless, not all measures are the correct ones and the effect of some studies may be distorted. That is why we try to evaluate the methods.

5.2.1 Hormones measurement

We have several possible ways how to measure individual´s level of hormones and we are particularly interested in basal testosterone and cortisol. Serum testing of hormones has long been accepted as the standard for measuring hormones, but it is also possible to use urine, saliva, hair and fingernail to assess a wide array of hormones. Some of the sample collection methods are more invasive such as serum (blood), urine, or saliva and some of them are non-invasive such as hair and fingernail. The latter two are new to the field of hormone testing and are rapidly evolving as mediums for cortisol. The official scales of the hormones contained in human body, often called reference values, have been set only for serum, urine and saliva as opposed to hair and fingernail that do not have such scales yet. The reference values indicate the boundaries between normal and abnormal values (Amballi et al., 2007). In this section, we also compare the methods of hormone testing. Each of them can provide valuable and important information, but also has its limitations.

5.2.1.1 Serum

Serum samples are not so common in economic laboratory experiments, but the naturally occurring data from blood samples can be useful. Serum has very well-

established reference ranges as it already has a long history. Serum testing is reliable and well-suited for testing reproductive hormones. It is useful for identifying endogenous hormone excesses or deficiencies. Serum tests require clinic staff and it can be bio-hazardous for them especially with subjects suffering from AIDS and hepatitis.

One of the limitations of serum hormones testing is the single-point testing, because hormones are secreted in a pulsing way during the day, so it is difficult to know whether the levels in serum represent a peak, valley, or something in between. Another limitation is that serum hormone levels do not usually increase when hormones are applied to the skin via cream or gel as a mean of direct administration. Additionally, the act of obtaining a sample via venipuncture could itself be a source of stress and increase cortisol (Brambilla et al., 2007).

5.2.1.2 Saliva

Saliva sample is the easiest and most used measure of hormone levels in experimental economics. Research assistants and subjects themselves with minimal training can easily collect saliva samples in most circumstances. It can be collected even under real life situations (e.g. at work, at home, etc.). Saliva has the advantage of being rather non-invasive as well as being accessible to most researches with availability of salivary assay protocols. Saliva sample, like serum, is a single-point collection, nevertheless, saliva also allows for easy multiple collections over a period of a day or month which can help elucidate abnormal hormonal patterns. Gavrilova & Lindau (2009) confirm a good validity of salivary sex hormone measurements on a large, population-based study of older adults in the United States.

Saliva can only be used to evaluate steroid hormones and Granger et al. (2004) identify other problems that can emerge with salivary testosterone. It can be substantially influenced during the process of sample collection and are sensitive to storage conditions when samples have been archived. Salivary testosterone levels are sensitive to the effects of blood leakage into the oral mucosa caused by micro-injuries and there are multiple restrictions regarding eating, drinking, gum-chewing, make-up use, and tooth-brushing. Moreover, Hayes et al. (2016) show that there are a wide variety of dietary factors that have been shown to influence salivary testosterone and

cortisol, plus smokers report altered salivary testosterone and cortisol compared to non-smokers.

5.2.1.3 Urine

Measuring hormones in urine is less common in clinical practice than either serum or saliva, but it is quite used in research. Not all urine hormone testing methods are equal. For instance, serial single-point urine collection does not account for individual differences in hormone secretion. A 24-hour urine collection is the preferred method for testing hormones that are secreted at night and during sleep and is used to evaluate steroid hormone metabolites. It allows that a measure of the total daily output can be obtained. On the other hand, it is cumbersome and time consuming, especially for women (Timmins, 2017).

5.2.1.4 Hair

Hair can be used to measure cortisol production. The first 1 cm of hair closest to the scalp represents approximately one month of cortisol production. Up to now, the majority of studies have investigated cortisol responses using samples of serum, saliva, or urine. Russell et al. (2012) claim that using of hair cortisol may be a good biomarker of chronic stress that enables researchers to accurately and retrospectively measures its production and intensity, because it assesses cortisol over longer time period. Unlike the previous sample methods, hair samples do not require any special storage condition prior the analysis. Unfortunately, there are no clinically relevant reference ranges established yet and there is also not enough evidence for the effect of natural hair color and cosmetic treatments on hair cortisol concentrations.

5.2.1.5 Fingernail

Fingernails may be capable of providing cumulative cortisol exposure. Fingernail analysis like hair may allow assessment of the accumulated hormone levels over a longer time period. Nejad et al. (2016) claim that cortisol is incorporated into hair and nails via similar cellular mechanisms. They both represent a non-invasive, cost effective means of collecting samples; however, hair analysis is not always possible such as in case of balding. According to Warnock et al. (2010), the nail samples

showed a significant increase in the cortisol during the putatively stressful period. But further studies are still required to validate fingernails as a reliable measure.

5.2.2 Proxy variable

As opposed to direct testing of hormone levels, we can also use a proxy variable for a particular hormone. In the case of testosterone, it can be the 2D:4D ratio, which is commonly considered to reflect the early exposure to testosterone in utero. Lower 2D:4D ratio indicates a higher prenatal testosterone exposure. Many researchers in experimental economics (Coates et al., 2009; and Pearson & Schipper, 2009) use this method as it is relatively easy to measure and calculate the ratio by scanning hands. In addition, the method is non-invasive.

On the other hand, precise measurements of 2D:4D are crucial for the detection of the correct associations as Brañas-Garza & Kovárık (2013) comment on Buser (2012), whose subjects self-reported whether they have shorter, equal, or larger ring than index finger in order to elicit prosocial attitudes. They claim that this elicitation method is inappropriate, because the scale and standard deviations of the 2D:4D ratio are typically too small to be easily captured with the naked eye. It generates a poor proxy for the ratio as it suffers from measurement errors. Moreover, using this variable in the regression analysis may lead to inconsistent estimates.

5.2.3 Direct administration

Direct administration of hormones in economic laboratory experiment is not that common as for medical purposes, and can be perceived as too invasive in case of an intravenous injection. But there are also many researchers who apply it. Most experimenters use the double-blind placebo-controlled design (Cueva et al., 2015; Riis-Vestergaard et al., 2018; and Wibral et al., 2012). The hormones intake can bear some health dangers, so to minimize the risks of possible interactions with the administration of either hormones, a qualified clinician should be present during the experiment.

There are several ways how to apply the hormone such as gelatine capsules, gel applied to the body that can be self-administered by the subjects at home, or

injection that can be seen as too invasive. A possible limitation of the hormonal administration procedure according to Cueva et al. (2015) is that it may not have induced peak behavioral effects at the time point outcome measures are collected.

In the study of Lovallo et al. (2006), repeated caffeine doses increased cortisol secretion over the day of observation and during periods of stress. In contrast to repeated cortisol administration, a single dose of cortisol does not alter the behavioral performance as found by Hsu et al. (2003) and Rada Ortner et al. (2013). In addition, cortisol administration reversibly decrease specific elements of memory performance in otherwise healthy individuals (Newcomer et al., 1999).

5.2.4 Statistical power

Design of the experiment can have substantial effect on the experiment´s results. If statistical assumptions and data characteristics are incorrect, it can lead to inaccurate estimates.

Statistical power is the probability of detecting an effect assuming that the effect is really present. There are two types of errors that can be made while using significance tests to decide about a null hypothesis. First, type I error that is incorrectly rejecting the null hypothesis (false positive) and second, type II error that stands for incorrectly accepting the null hypothesis (false negative). It is well recognized that low statistical power increases the probability of a type II error. Low statistical power also leads to increased risk that statistically significant results will actually be falsely positive. For instance, Christley (2010) found that if there is a high probability that the null hypothesis is true, statistically significant findings are even more likely to be falsely positive. Higher statistical power can be achieved by higher effect size and sample size, or by smaller standard deviation.

The sample size plays an important role in relation to a result of the research. It is one of the features where laboratory and field experiments differ. Many experiments use too small sample size to reveal significant conclusions. Nevertheless, sample size is usually dictated by logistical and budgetary constraints. Recent research indicates that statistically significant findings from studies with small

sample sizes should be treated with increased scepticism, especially in cases where there is a reasonable chance that the null hypothesis is true (Ioannidis et al., 2014).

Unfortunately, there is an unusually large number of significant results of underpowered studies being published that reflects a study publication and reporting bias, where true results of large studies are less likely to be published when they reach non-statistically significant findings (Vadillo et al., 2016).

In addition, a lot of hormone experiments were conducted as gender specific. Majority of researchers use only men in their hormone analysis (Borráz-León et al., 2017; Neave et al., 2003; and Wibral et al., 2012). Gender specific research will vary in findings as women and men have different hormone levels by nature.

5.3 Nurture vs nature

There is a question, whether the individuals´ differences in competitive and risk-taking behavior are caused by genetic inheritance and other biological factors such as the hormones that are set by nature, or whether they are mainly influenced by nurture during the initial phase of our lives. Nurture is generally explained as the influence of external factors, including our early childhood experiences, social relationships, learning, and culture. Nurture and nature interaction is also a very important factor, because nurture enables the expression of nature.

In the research, there is a consistent evidence for both nurture and nature influences on attitudes to competitiveness and risk-taking (Niederle & Vesterlund, 2011). For instance, Dohmen et al. (2011) found that individuals with highly educated parents are significantly more likely to choose risky outcomes. Moreover, understanding the extent to which risk attitudes are innate or shaped by environment is important for policy.

Nurture and nature influence is most often associated with gender differences in experimental economics. Women and men are considered to be innately different (Lawrence, 2006). The substantial gender differences in hormone levels have been already discussed earlier in this thesis. Gneezy et al. (2009) observed an important link between culture and behavioral traits that influence economic outcomes by

determining gender differences in competitiveness on patriarchal and matrilineal societies. They found a reversal of the gender gap at Khasi matriarchal society in India that may indicate a possibility to nurture women to be more competitive.

In addition, Booth & Nolen (2012) suggest an important implication of either influence. If risk attitude is innate, under-representation of women in certain areas may be solved only by changing the way how men and women are rewarded. On the other hand, if risk attitude is primarily shaped by the environment, changing the educational or training context could help to address under-representation of women in some top positions.

6 Data

In this section, we describe in detail our dataset that we use for the analysis to test our hypothesis. It is important to have a valid dataset so we can draw some significant conclusions based on it. A laboratory economic paid experiment is an incentive compatible method and thereby allows for better control over confounding factors and better predicts real life behavior.

6.1 Experiment

We ran a controlled laboratory experiment with a student subject pool to be able to investigate our research questions. The experiment took place in the Laboratory of Experimental Economics at University of Economics in Prague in 2014 and 2015 primarily with undergraduate students, majoring mostly in economics, business and related fields. The experiment was conducted in the Czech language, was programmed in Z-tree (Fischbacher, 2007) and each of 12 sessions consisted of eight subjects (four males and four females). The participants took part in the control group during a modified version of the Trier Social Stress Test for Groups (TSST-G). The main research question of the experiment and its full design are addressed in Cahlíková et al. (2016) while here we investigate other issues as described above. Participants were also given instructions to abstain from fatty food, heavy exercise, smoking and intake of any medical substances prior to the experiment, in order to avoid distorting cortisol and testosterone measurement.

6.2 Design of the experiment

Here we present only the parts of design relevant for our study. The full design of the experiment is described in the paper of Cahlíková et al. (2016).

Before the subjects came for the experiment, they had filled in an online questionnaire with a battery of questions for the measurement of the trait anxiety. At the beginning of the experiment, subjects were asked to answer on a set of questions

of their personality scales called the Big Five personality traits (Costa & McCrae, 1992), were presented with the general instructions for the experimental tasks, and they were also asked on a few questions to check their understanding of the rules of the experiment. The detailed instructions for each task were presented on-screen just before the execution of the task.

Before the first experimental task of the experiment, the subjects´ saliva samples were collected from which testosterone and cortisol levels were measured. The samples were stored in -20°C and were shipped for analysis to the Department of Biopsychology at the Technical University of Dresden immediately after the particular batch of sessions had ended. Next, we used the same method to measure competitiveness as in Gneezy et al. (2017) based on Niederle & Vesterlund (2007). Participants solved real math tasks adding up sets of four two-digit numbers and were rewarded in the first two-minute round using a piece-rate scheme while in the second round using a forced tournament scheme, in which payoff depended on performance compared to another randomly selected participant.

Then, subjects chose ex-ante how they wanted to be compensated for their future performance in the counting portion of the upcoming task. Having experienced both compensation schemes, they were asked to choose which of the two schemes they want to apply for their next performance. They did so by linearly splitting 100 points between the tournament and the piece-rate compensation schemes. For each point invested in the piece-rate scheme, they earned 0.25 CZK per correct answer. For each point invested into the tournament compensation scheme, they earned 0.5 CZK per correct answer, but only if they had more correct answers in this task than another randomly selected participant in the previous task, and received nothing per each point invested in the tournament scheme if they answered fewer questions. In case of a tie, each point invested in the tournament account was rewarded according to the piece-rate scheme. The subjects' understanding of this payoff structure was facilitated by allowing them test various combinations of the point distribution on-screen to directly see the resulting payoffs in cases of both a victory as well as loss in the tournament, before they made their actual choices.

The choice of compensation scheme for future performance in the competitive task is our main measure of participants’ willingness to compete similarly as in

Gneezy et al. (2017). The choice of compensation scheme cannot be driven by prosocial concerns or expectations, regarding who self-selects into the tournament, as subject's performance in competitive task was always compared to the previous task performance of another randomly selected subject and this information was highlighted in the instructions. Hence, subjects knew that their decision to enter the tournament would not have any payoff consequences for anyone else.

After this, we also conducted another task to measure risk preferences using a setting based on Dohmen et al. (2011). The measure of participants´ risk attitude involved choices over real-stakes lotteries. Subjects were asked to repeatedly choose between a lottery, which is always kept the same at 240 CZK versus 0 CZK with 50% probability each, and different safe payments, which are gradually increasing from 0 CZK to 240 CZK in the steps of 20 CZK. Since the expected value of the lottery is 120 CZK, weakly risk-averse subjects should prefer safe options that are smaller than or equal to 120 CZK over the lottery. Only risk-taking subjects should decide for the lottery when the offered safe option is greater than 120 CZK.

If the individual's behavior is consistent, then the row where the subject switches preferences indicates the individual certainty equivalent, i.e. the safe amount which makes the individual indifferent to choosing or not choosing the lottery. This procedure gives subjects an incentive to choose according to their true preferences in each row, and thus is incentive compatible. Repeated switching between the lottery and safe payment was allowed in the design, and as such would either refer to improper understanding of the task, or general indifference between the two alternatives (Andersen et al., 2006). In our sample, the share of consistent answers was 94.7%.

At the end of the experiment, participants´ both hands were scanned and the 2D:4D ratio was calculated based on the scan as the ratio between the length of their second finger and the fourth finger. The scans were then assessed for the 2D:4D ratio using the program Autometrics 2.2.

6.3 Summary statistics

In this part, we describe the main summary statistics of our variables, see Table 1Table 1 below (gender-differentiated). Overall, we have 96 participants in our experiment with the same proportion of women and men making both 48. The average age of our participants is 21.5 years as the experiment was conducted on university students. We further use height in our analysis, because it was shown to have a substantial effect on risk taking in the previous research (Dohmen et al., 2011). The height is in the range from 154 cm to 196 cm with the average of approximately 174 cm. In the table you can also see specific values of the testosterone and cortisol levels and the 2D:4D ratio values. In addition, we also have 21 smokers in our sample. Smoking is considered to be associated with the willingness to take risk mostly in the health domain (Ert et al., 2013; and Jenks, 1992).

Table 1: Summary statistics by gender

Variable		**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Female fraction		96	0.50	0.50		
Age	Men	48	21.40	1.59	19	27
	Women	48	21.60	1.79	18	30
Height	Men	48	180.92	6.24	164	196
	Women	48	167.69	5.84	154	183
Testosterone	Men	48	96.48	50.71	5.51	318.08
	Women	48	25.30	18.92	5.21	98.68
Cortisol	Men	48	14.41	7.13	0.97	32.81
	Women	48	10.01	4.36	2.81	20.04
2D:4D ratio	Men	48	0.96	0.37	0.88	1.03
	Women	48	0.98	0.04	0.88	1.06
Competitiveness	Men	48	63.52	31.68	0	100
	Women	48	37.48	25.38	0	100
Risk-taking	Men	48	6.58	1.61	3	13
	Women	43	5.79	1.81	3	13

On the histograms below (Figure 2 and Figure 3), you can see the distribution of participants´ decision on willingness to compete for men and women, respectively. From simple visual inspection we can notice that women invested lower amount during the task. The mean of compensation scheme is 63.5 for men and 37.5 for women. In the Appendix, you can also find the distribution of participants´ decision on risk taking for both genders. The mean of certainty equivalent is approximately 6.6 for men and 5.8 for women. We have only 91 observations in risk-taking task, because five subjects were inconsistent in their preferences (they switched more times between the options).

Detailed statistics of the dataset are available upon request.

Figure 2: Distribution of participants´ decision on willingness to compete - male

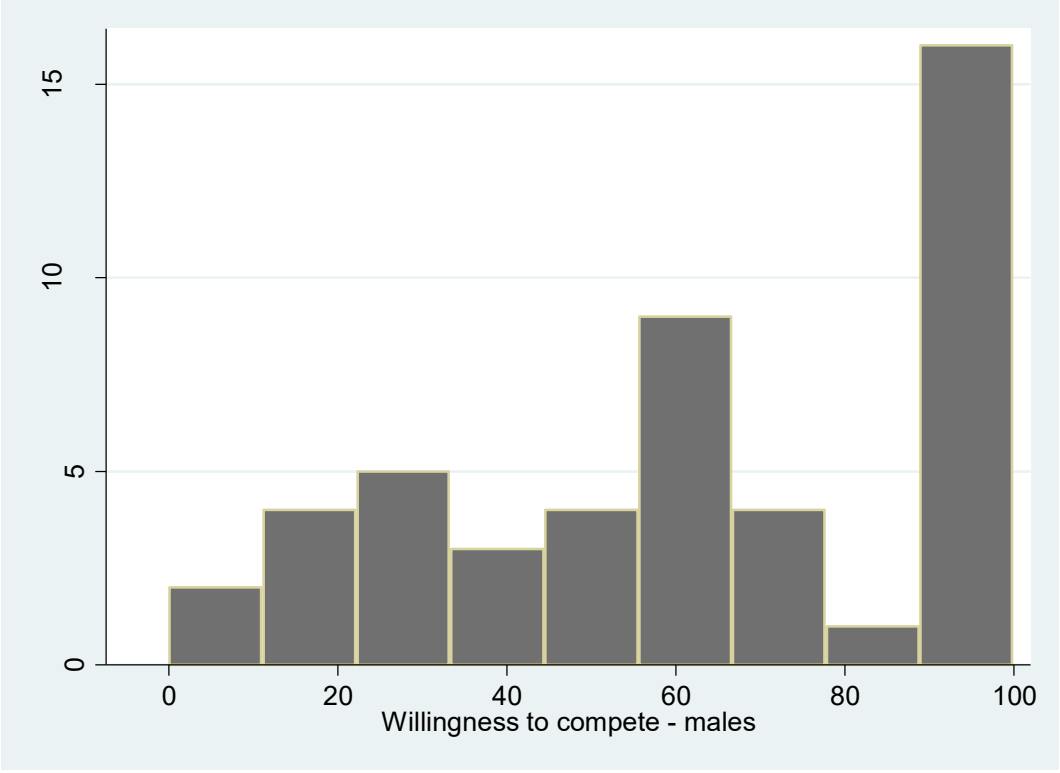
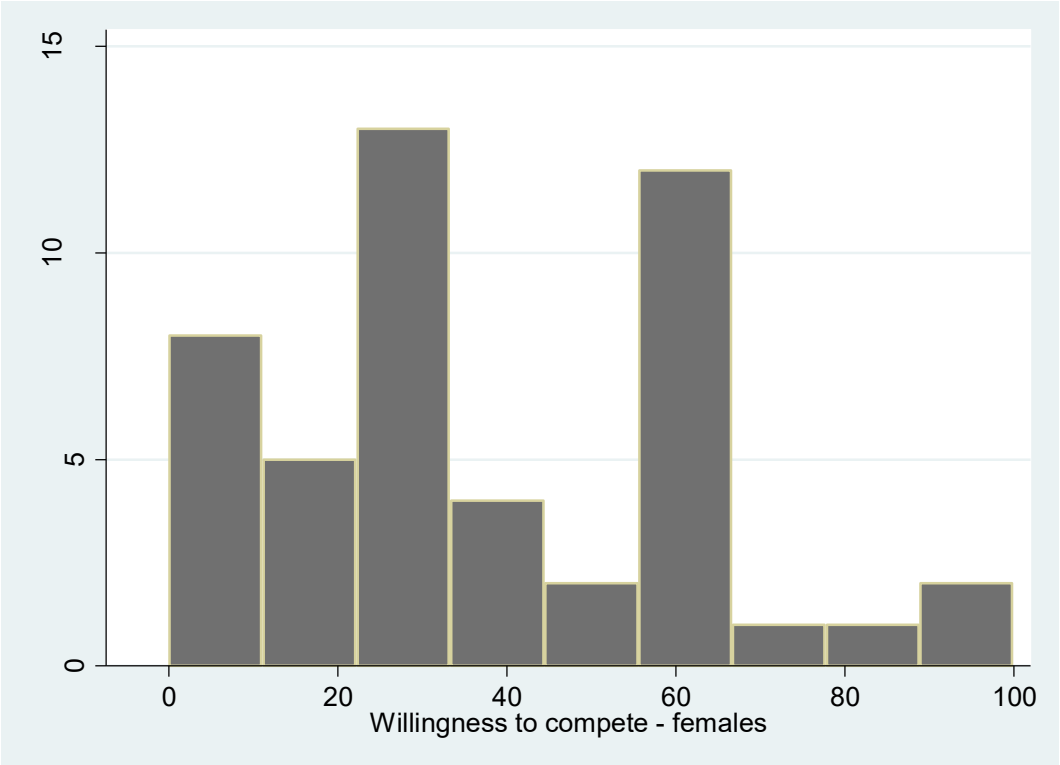


Figure 3: Distribution of participants´ decision on willingness to compete - female



As we expected, testosterone and gender (being a female) are highly correlated (see Table 2). We have already discussed the nature of biological differences between women and men earlier and we concluded that men have substantially higher levels of testosterone.

Table 2: Correlation between testosterone and gender

	Testosterone	Female
Testosterone	1.0000	
Female	- 0.7383	1.0000

Next, in Figure 4 and 5 you can see participants´ basal testosterone distribution separately for both genders. We run a Two-sample t test to check that the gender difference in testosterone distribution is really significant and it was confirmed (t = 10.557).

Figure 4: Distribution of males´ testosterone

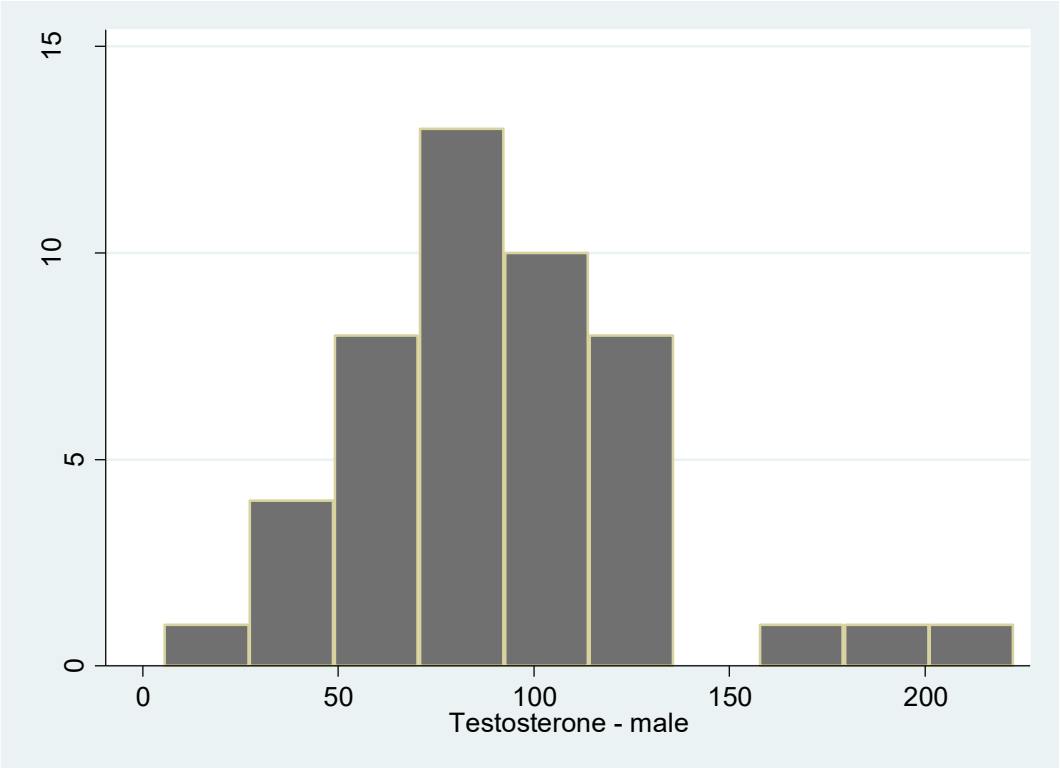
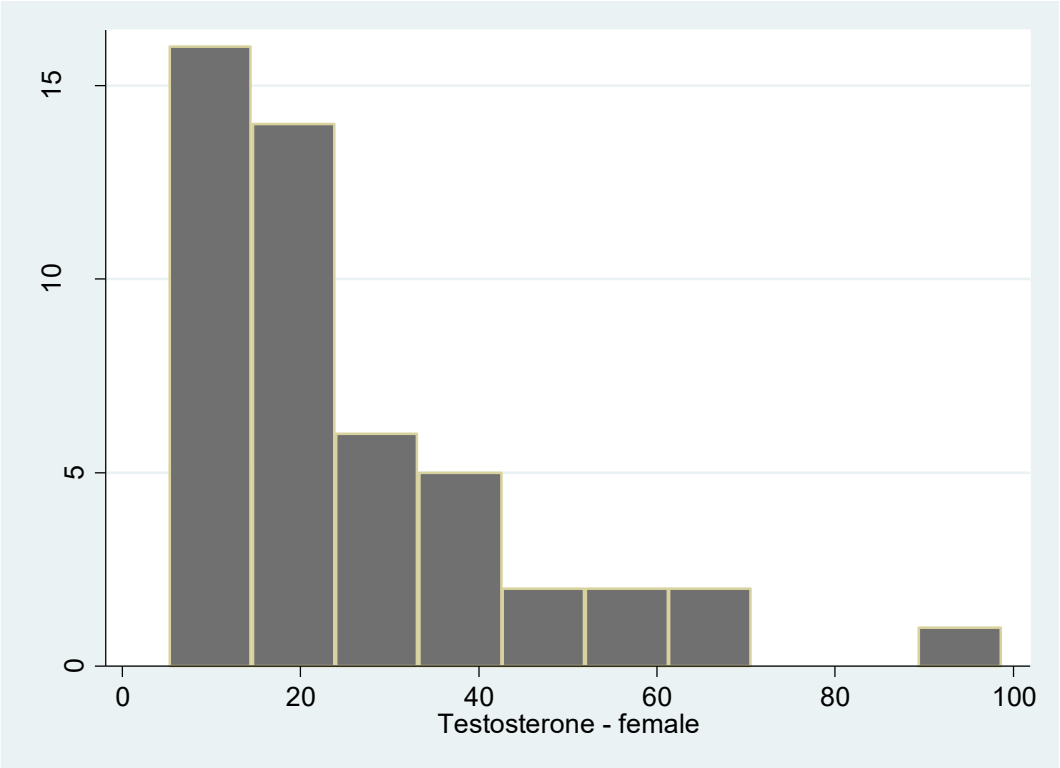


Figure 5: Distribution of females´ testosterone



7 Results

In this part, we analyze our dataset, which was already described in detail, in order to test our hypotheses. For that purpose, we use the statistical software Stata and standard statistical methodology based on Aiken & West (1991). We start with analyzing the main research question whether basal testosterone affect individual´s willingness to compete. Next, we investigate gender differences in attitudes to competition as we suspect that there is a level difference between the genders. We also control for potentially influential variables to check the robustness of results. Finally, we deal with the dual-hormone hypothesis for willingness to compete and take risk separately for men and women.

Before we start with the actual regressions, we need to check our data for outliers. We have one outlier in testosterone data that is more than five standard deviations above the mean. We remove it in order to not distract our results. Some of the previous studies such as Bedgood et al. (2014) and Mehta & Josephs (2010) use log transformation of their testosterone and cortisol data, respectively, to reduce the skewness, therefore it can distort the two hormones interaction as they transformed only one of the hormones. We run a Jarque-Bera test on our data for both genders and find no significant skewness for cortisol data (p value > 0.2) and slightly skewed testosterone data (p value ~ 0.01), hence we decided not to transform our data to better interpret their interaction term.

7.1 The effect of basal testosterone on willingness to compete

In this part, we want to analyze the data in order to find out whether our basic hypothesis that basal testosterone affects individual´s willingness to compete holds.

7.1.1 Testosterone and willingness to compete: naive specification

A first, naive attempt of how to test the hypothesis that basal testosterone directly affects the individual´s willingness to compete would be not to account for gender. The regression is represented by the general equation of linear model:

$$y = \beta_0 + \beta_1 * x_1$$

In our case:

$$Willingness\ to\ compete = \beta_0 + \beta_1 * Testosterone$$

From the Table 3 below, we can see that the effect of testosterone is statistically significant at 5% level. The results indicate that 1 point increase in the testosterone level, ceteris paribus, increases the individual´s willingness to compete approximately by 0.186 points. The basic analysis confirms our hypothesis that basal testosterone affects positively individual´s decision to compete. Nevertheless, we have not controlled for the effect of gender yet, so the results may be driven by a level difference between the genders and therefore we cannot draw any final conclusions from it now.

Table 3: The effect of testosterone on willingness to compete

	Willingness to compete
Testosterone	0.186**
	(0.074)
N	95
R^2	0.071
F	6.383

We use OLS regression technique and the regression includes a constant. Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

7.1.2 Gender differences

We also want to investigate the gender differences in willingness to compete. From the regression in Table 4, column (1), we can see a robust gender difference that is statistically significant at 1% level, meaning that men invested, on average, about 26 points more into the competition than women. In the next regression (2) we combine both variables, i.e. gender and testosterone, but the results are influenced by the correlation among these two variables suggesting that if we control for gender, testosterone does not explain anything regarding willingness to compete. Next, in the last regression (3) we also add cortisol and find no statistically significant effect of cortisol on willingness to compete at any reasonable level.

Table 4: Gender differences in willingness to compete

	Willingness to compete		
	(1)	(2)	(3)
Female	-26.04***	-31.12***	-32.29***
	(5.859)	(9.155)	(9.184)
Testosterone		-0.690	-0.041
		(0.102)	(0.101)
Cortisol			-0.733
			(0.468)
N	96	95	95
R^2	0.174	0.183	0.198
F	19.76	10.15	7.02

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

As we expected, there are substantial gender differences in competitive behavior as well as in levels of testosterone, so for better clarity we present the regression results separately for men and women from now on, even though we lose statistical power. In this case we can distinguish the effect of testosterone from other behaviors that differ starkly by gender. Now, we analyze our main research question and other factors potentially influencing competitiveness, which we use as control variables, will follow in the next part (Robustness check). To find out whether testosterone works differently for men and women, we test the effect of testosterone separately for both genders. Surprisingly, we find no statistically significant effect of basal testosterone on willingness to compete for men, see Table 5. And moreover we find a negative effect of testosterone for women saying that one point increase in testosterone leads to reduced competitiveness about 0.343 points and it is statistically significant at 5% level.

Table 5: The effect of testosterone on willingness to compete by gender

	Willingness to compete	
	Male	Female
Testosterone	-0.004	-0.343**
	(0.123)	(0.165)
N	47	48
R^2	0.000	0.065
F	0.001	4.315

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

7.1.3 Robustness check

Next, we add other potentially significant explanatory variables to check whether the effect is actually driven by the testosterone or by these variables. We add results from the math task (piece-rate) as a control variable to account for differences in abilities. Next, we add basal cortisol as the second investigated hormone and find no

statistically significant effect on willingness to compete. Nevertheless, the direction of the cortisol effect is stable and negative for both genders suggesting that higher cortisol levels decrease competitiveness. We also use anxiety that was measured by the trait anxiety inventory. We find that anxiety negatively affects the willingness to compete and the effect is statistically significant even at 1% level but only for men. One point increase in anxiety decreases ceteris paribus the willingness to compete approximately about 1.32 points. We further find that male smokers are less willing to compete and the effect is statistically significant at 5% level. It implies that male smokers invested almost about 19 points less than non-smokers in competition. We find no support that individual´s height affects competitiveness as it is mostly known to be associated with the attitudes to take risk. Not surprisingly, being a risk taking person positively affects willingness to compete and it is statistically significant at 1% level for both genders. All the regressions results can be seen in the Table 6 (men) and Table 7 (women) below. In the Appendix, we also present the regression with all the control variables together to show that qualitatively our results hold.

Overall, we can observe a robust negative effect of basal testosterone on willingness to compete for women and no support for the effect among men. Therefore, we proceed to the dual-hormone hypothesis that might explain these findings.

In the Appendix, you can further see the analysis of the effect of the Big Five personality traits measured by NEO Personality Inventory on competitiveness used as other additional control variables to see whether the effect of testosterone is driven by personality dimensions. It confirms the previous findings. Moreover, we find a statistically significant effect of openness on willingness to compete for men at 5% level.

Table 6: Robustness check for testosterone - men

	Willingness to compete			
	(1)	(2)	(3)	(4)
Testosterone	0.034	0.0528	-0.028	0.042
	(0.132)	(0.104)	(0.106)	(0.115)
Cortisol	-0.516	-0.659	-0.650	-0.507
	(0.590)	(0.648)	(0.634)	(0.538)
Math´s task ability	1.624	1.636	1.490	1.870
	(1.412)	(1.443)	(1.448)	(1.382)
Anxiety	-1.316***			
	(0.406)			
Smoking		-18.980**		
		(9.406)		
Height			-1.104	
			(0.806)	
Risk taking				9.832***
				(3.361)
N	47	47	47	47
R^2	0.143	0.104	0.085	0.290
F	2.643	1.819	0.884	4.241

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

Table 7: Robustness check for testosterone - women

	Willingness to compete			
	(1)	(2)	(3)	(4)
Testosterone	-0.291*	-0.292*	-0.292*	-0.261*
	(0.157)	(0.157)	(0.164)	(0.147)
Cortisol	-0.503	-0.785	-0.730	-0.244
	(0.668)	(0.584)	(0.605)	(0.595)
Math´s task ability	1.351	1.793	1.539	1.050
	(1.554)	(1.332)	(1.457)	(1.322)
Anxiety	-0.450			
	(0.444)			
Smoking		-9.737		
		(10.55)		
Height			-0.061	
			(0.638)	
Risk taking				9.007***
				(2.142)
N	48	48	48	43
R^2	0.121	0.125	0.101	0.286
F	2.191	2.566	1.943	4.352

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

7.1.4 The 2D:4D ratio

Based on the literature mentioned earlier, the 2D:4D ratio reflects the prenatal exposure to testosterone, and thus they should be closely associated. We find a negative correlation between basal testosterone levels and the ratio (see Table 8) that is in line with our expectations, because lower 2D:4D ratio is considered to be associated with higher testosterone levels. Nevertheless, it is not significant at any reasonable level.

Table 8: Correlation between testosterone and 2D:4D ratio

	Testosterone	2D:4D ratio
Testosterone	1.0000	
2D:4D ratio	-0.127	1.0000

We find no statistically significant effect of the 2D:4D ratio on willingness to compete for men, but the direction of the effect is in line with the general theory suggesting that lower ratio implies higher competitiveness. On the other hand, we find a positive effect of the ratio for women that is statistically significant even at 1% level. It corresponds to the findings on testosterone which is opposite to the existing research (Table 99, column 1). We also analyze the interaction of testosterone and the ratio and find that the effect of testosterone on competitiveness for women depends also on the 2D:4D ratio (Table 9, column 3). The results suggest that the 2D:4D ratio is a predisposition for reactivity to the current testosterone level in our body, and therefore those who have fewer receptors have a different response to the presence of testosterone.

Table 9: The effect of 2D:4D ratio on willingness to compete

	Willingness to compete					
	(1)		(2)		(3)	
	Male	Female	Male	Female	Male	Female
2D:4D ratio	-54.45	148.2***	-57.27	191.8***	196.1	73.76
	(101.1)	(58.03)	(107.8)	(66.07)	(228.8)	(100.4)
Testosterone			-0.0135	-0.414	3.409	-4.313**
			(0.133)	(0.146)	(3.214)	(2.098)
Testos*2D:4D					-3.486	3.973**
					(3.338)	(2.013)
N	48	48	47	48	47	48
R^2	0.004	0.072	0.005	0.175	0.031	0.195
F	0.290	6.521	0.145	6.229	0.459	6.363

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

7.2 Dual-hormone hypothesis for willingness to compete

For testing the next hypothesis we use the interaction of basal testosterone and cortisol. We again analyze the data separately for women and men for an easier interpretation of coefficients, because we have already found that there are robust gender differences in attitudes to competitiveness. The regression for the dual-hormone hypothesis is represented by the general equation of linear model:

$$y = \beta_0 + \beta_1 * x_1 + \beta_2 * x_2 + \beta_3 * x_1 * x_2$$

And in our case:

$$Willingness\ to\ compete = \beta_0 + \beta_1 * Testosterone + \beta_2 * Cortisol + \\ + \beta_3 * Testosterone * Cortisol$$

We find no statistically significant support for the dual-hormone hypothesis for men and women regarding willingness to compete (see Table 10). It means that when we account for gender, then the basal testosterone and cortisol cannot predict individual´s competitive behavior, even in the interaction.

Table 10: Dual-hormone hypothesis – willingness to compete

	Willingness to compete	
	Male	Female
Testosterone	0.002	-0.557
	(0.360)	(0.362)
Cortisol	-0.624	-1.292
	(2.224)	(0.828)
Testosterone*Cortisol	0.006	0.021
	(0.023)	(0.019)
Math´s task ability	1.488	1.563
	(1.543)	(1.464)
N	47	47
R^2	0.042	0.108
F	0.690	2.039

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

7.3 Dual-hormone hypothesis for risk taking

At first, we find strong gender differences in attitudes to risk that is well established consensus and the effect is statistically significant at 5% level, see Table 11. Therefore, we again present the results of dual-hormone hypothesis for risk taking separately for men and women to ensure greater clarity. The results say that women chose, on average, about approximately 0.8 points less risky choices than men.

Table 11: Risk taking – gender differences

	Risk taking
Female	-0.793**
	(0.360)
N	91
R^2	0.052
F	4.840

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01

For the dual-hormone hypothesis on risk taking, we use the same interaction of basal testosterone and cortisol as in the previous dual-hormone hypothesis for willingness to compete. We find no support for the dual-hormone hypothesis for men. But we find statistically significant effect of the two investigated hormones interaction on risk taking even at 1% level for women. Higher basal testosterone again reduces willingness to take risk at women as in the competitiveness analysis. The results suggest that cortisol antagonizes the effect of testosterone on willingness to take risk. A one point increase in female´s testosterone causes change in risk taking by (0.004*ΔCortisol – 0.071) points that is minus 0.067 points if the cortisol stays constant, see Table 12. The results contradict our expectations that higher testosterone increases risk taking only when cortisol is low.

Table 12: Dual-hormone hypothesis – risk taking

	Risk taking	
	Male	Female
Testosterone	-0.020	-0.071***
	(0.013)	(0.023)
Cortisol	-0.114	-0.150*
	(0.078)	(0.079)
Testosterone*Cortisol	0.001	0.004***
	(0.001)	(0.001)
N	47	43
R^2	0.030	0.153
F	0.811	3.672

We use OLS regression technique and the regression includes a constant.
Robust standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

7.3.1 Robustness check

We also use other potentially influential variables including height and smoking factor that are generally considered to affect risk taking, anxiety, math´s ability, 2D:4D ratio, and the Big Five personality traits to check the robustness of the dual-hormone hypothesis on risk taking for women. Surprisingly we find no significant effect of individual´s height on willingness to take risk, the same holds for smoker.

In all cases, the effects are robust and support our finding that testosterone´s effect on risk taking depends also on cortisol for women, see Table 13. Interestingly, after controlling for anxiety, we find also statistically significant effect of the two hormones interaction at 10% level for men, see Table 14. Interestingly, the effect goes in the opposite direction than in Mehta et al. (2015b) who study a similar question, but only with reported measures. It suggests that males who are more prone to anxiety respond differently to hormones presence. In the Appendix, we further

present the Big Five personality traits as control variables and find that results for men and women hold even when accounting for that.

Table 13: Robustness check for risk taking – females

	Risk taking				
	(1)	(2)	(3)	(4)	(5)
Testosterone	-0.071***	-0.072***	-0.071***	-0.068***	-0.067**
	(0.024)	(0.023)	(0.024)	(0.023)	(0.024)
Cortisol	-0.133	-0.150*	-0.138	-0.140*	-0.102
	(0.085)	(0.081)	(0.093)	(0.079)	(0.97)
Testosterone*Cortisol	0.004***	0.004***	0.003**	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Anxiety	-0.030				-0.052*
	(0.031)				(0.031)
Smoking		0.203			0.315
		(0.701)			(0.488)
Height			0.039		0.029
			(0.053)		(0.055)
2D:4D ratio				0.591	2.687
				(5.268)	(5.277)
Math´s ability					-0.120
					(0.114)
N	43	43	43	43	43
R^2	0.170	0.155	0.168	0.144	0.209
F	2.907	3.267	5.170	2.593	3.824

We use OLS regression technique and the regression includes a constant.
Standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

Table 14: Robustness check for risk taking - males

	Risk taking				
	(1)	(2)	(3)	(4)	(5)
Testosterone	-0.026*	-0.021	-0.021	-0.019	-0.029**
	(0.014)	(0.013)	(0.013)	(0.014)	(0.013)
Cortisol	-0.159*	-0.108	-0.118	-0.109	-0.165*
	(0.084)	(0.085)	(0.078)	(0.082)	(0.091)
Testosterone*Cortisol	0.002*	0.001	0.001	0.001	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Anxiety	-0.047*				-0.063*
	(0.024)				(0.035)
Smoking		0.362			0.802
		(0.769)			(0.941)
Height			-0.018		-0.022
			(0.042)		(0.049)
2D:4D ratio				1.737	1.261
				(4.608)	(4.766)
Math´s ability					-0.039
					(0.091)
N	47	47	47	47	47
R^2	0.077	0.039	0.035	0.032	0.124
F	1.852	0.884	0.634	0.783	1.080

We use OLS regression technique and the regression includes a constant.
Standard errors are stated in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

8 Discussion of results

In this chapter, we go through the results from our analysis and their possible implications for a real life. Further, we also discuss how our findings fit into the existing literature and whether they are in line with our hypotheses.

We have substantial amount of 96 participants in our experiment that can produce robust results. And what more, we have gender-balanced dataset that allows us to compare the gender differences. In addition, our participants´ age is in a narrow range as they are all university students that ensure a small variation in this dimension. It has been shown that individual´s testosterone levels decrease with age, so the results are not influenced by this fact and we could focus more on other dimensions.

8.1 The effect of basal testosterone on willingness to compete

We cannot confirm our hypothesis that higher levels of basal testosterone lead to increased willingness to compete. As opposed to most of the recent literature (Eisenegger et al., 2017; and Zilioli & Watson, 2014), we find no support for the effect of testosterone on competitiveness among men similarly as Edwards et al. (2006); and Schipper (2015). Moreover, we find significant negative effect of basal testosterone on willingness to compete for women, which is against the current trend of literature.

8.1.1 Gender differences

As expected, we find a large level difference in basal testosterone across gender. We also replicate significant gender differences in willingness to compete that corresponds to general research (Croson & Gneezy, 2009; and Niederle & Vesterlund, 2007). The level of testosterone naively seems to be one of the drivers of

gender differences in competitive behavior as women have, on average, substantially lower levels of this hormone. But basal testosterone has no significant inter-individual effect on willingness to compete once gender is accounted for.

8.1.2 Other influential variables

We find no statistically significant support for cortisol effect on willingness to compete. Nevertheless, the direction of the effect is stable and negative that is in line with our expectations and the general research for cortisol.

We find a negative correlation between testosterone and the 2D:4D ratio that corresponds to our expectations as it is supposed to be a prenatal exposure to testosterone. The positive effect of the 2D:D4 ratio on competitiveness found among women corresponds to our results on testosterone that is in contrary to other papers. Nevertheless, we find no effect for men, for instance, as Pearson & Schipper (2009).

Our finding about the role of anxiety on competitive behavior is a novelty, because it has not been much investigated in this context so far. The found effect is significant only for men and implies that higher level of trait anxiety decreases competitiveness. Definitely, it deserves further research as a promising predictor for human behavior in general. In addition, male smokers in our sample are less willing to compete that seems to be rather surprising as it has been shown by many studies that smokers are more willing to take risk (Ert et al., 2013; and Jenks, 1992).

8.2 Dual-hormone hypothesis for willingness to compete

Based on the results of our analysis, we cannot confirm the dual-hormone hypothesis for willingness to compete. There might be many possible reasons for these findings. Other studies use different measurement techniques for competitiveness. For instance, Mehta & Josephs (2010) use a Number Tracking Task from a test on a type of intelligence called spatial processing speed. We use a simple math task and it can draw different results and even causes false positive error. Moreover, many

researchers (Bedgood et al., 2014; Mehta & Josephs, 2010; and Mehta et al., 2015) use transformed data of at least one of the investigated hormones that might be conducted in order to reach significant result.

Our non-significant result on dual-hormone hypothesis for willingness to compete also imply that there might be publication bias as there are mostly published significant results of underpowered studies, whereas true results of large studies are less likely to be published when they reach non-statistically significant findings (Vadillo et al., 2016).

8.3 Dual-hormone hypothesis for risk taking

Firstly, we replicate the consensus that women are more risk averse than men (Croson & Gneezy, 2009; and Charness & Gneezy, 2011). It might help to adjust, for example the form of admission procedures, so that they would be gender balanced.

We can confirm the dual-hormone hypothesis for risk taking but only for women and with opposite direction of the testosterone´s effect than expected based on other studies. The significant effect holds even after controlling for other influential variables and stays robust. For men, we find support but only after controlling for anxiety, but not in other specifications which leads us to conclude that there is no general relationship, as in the previous case.

Our findings help to explain some ambiguous results in testosterone research on willingness to compete, because there are studies suggesting that cortisol antagonize the relation between testosterone and human behavior (Tilbrook et al., 2000) and we confirm it in case of women. The results imply that we need to take into account both investigated hormones.

9 Conclusion

The main aim of this thesis is to contribute to the growing body of studies focused on the role of hormones in the economic behavior, particularly in the competitive behavior and risk-taking. We specifically focus on the hormones testosterone and cortisol and their interaction usually called the dual-hormone hypothesis. We want to know to what extent economic behavior and outcomes are biologically determined and if the effect is significant for men and women too. Hormones contained in our bodies may critically influence our financial decision making.

Testosterone has traditionally been shown to influence various economic behaviors (Nadler et al., 2017). Recently, there is a tendency to observe the effect of both hormones, particularly their interaction, because some studies suggested the possibility that cortisol may antagonize the relation between testosterone and human behavior (Tilbrook et al., 2000). The novel dual-hormone hypothesis was proposed to account for the inconsistent findings in testosterone research on human social behavior including aggression and dominance (Carré & Mehta, 2011; and Mehta & Josephs, 2010).

We shed a new light on correlation between willingness to compete and investigated hormones by using and extending the design of Niederle & Vesterlund (2007) and Gneezy et al. (2017) for our experiment. We cannot find any significant effects of basal testosterone on willingness to compete among men as opposed to the most of the recent literature. Moreover, we find for women that higher levels of testosterone decrease competitiveness and risk taking.

Similarly as Niederle & Vesterlund (2007) and Gneezy et al. (2017) we find significant gender differences in willingness to compete. The findings on gender differences in willingness to compete are robust and generally confirmed; therefore our thesis contributes to overall understanding of this consensus. It indirectly supports the fact that men generate larger price bubbles and overtrade more than women (Croson & Gneezy, 2009; and Eckel & Füllbrunn, 2015). It can also help to explain why men hold a vast majority of trading jobs on financial markets.

Furthermore, the gender differences might influence the outcomes of entire labor market as according to Buser et al. (2017), the willingness to compete predicts career choices along the whole ability distribution.

Next, as expected we find a negative correlation between basal testosterone and the 2D:4D ratio and positive effect of the ratio on competitiveness among women, but no effect for men. We further focus on the mediating role of human personality on competitive behavior and among other things we find that being long-term anxious is associated with lower competitiveness for men.

Based on our results, we cannot confirm the dual-hormone hypothesis for willingness to compete. We add another analysis to dual-hormone hypothesis research in relation to competitive behavior just to minor studies that were conducted on this topic so far (Mehta & Josephs, 2010; and Mehta et al., 2015b), but there are still no clear results. On the other hand, we confirm the dual-hormone hypothesis on risk taking but only for women. Moreover, we find negative effect of testosterone on risk taking among women. The effect of this risk dual-hormone hypothesis for women is robust even after controlling for additional influential variables. In addition, we confirm the consensus that women are more risk averse than men.

Note that, if we had only men in the experiment we would not find almost any significant results. It implies that hormonal studies in experimental economics with null findings that use only men-based sample (Neave et al., 2003; Wibral et al., 2012) say nothing about women how their hormonal levels influence their behavior, and our findings suggest that there are robust significant effects. It is one of the contributions of this thesis as we highlight and encourage that the research on female´s hormones is also important for better understanding of their behavior.

Research on the dual-hormone hypothesis is still in its early stages and there are rather inconsistent findings on this topic. The current research has some methodological limitations that should be addressed in future studies. Testosterone and especially cortisol levels fluctuate throughout the day and respond to various environmental factors, which should be minimized, but not completely mitigated in the current study. The dual-hormone hypothesis has been tested primarily in correlational studies so far (Bedgood et al., 2014; Mehta et al., 2015a). Our

recommendation for further research is the direct administration of both hormones. Experimental designs are needed in which hormone concentrations are exogenously manipulated, i.e. experiments that simultaneously increase testosterone and suppress cortisol levels.

To sum up, based on the results of our analysis and current literature we are able to conclude that there are still many inconsistencies regarding hormones and human behavior, specifically willingness to compete. Moreover, there is a substantial part of the competitive behavior that has not been investigated yet.

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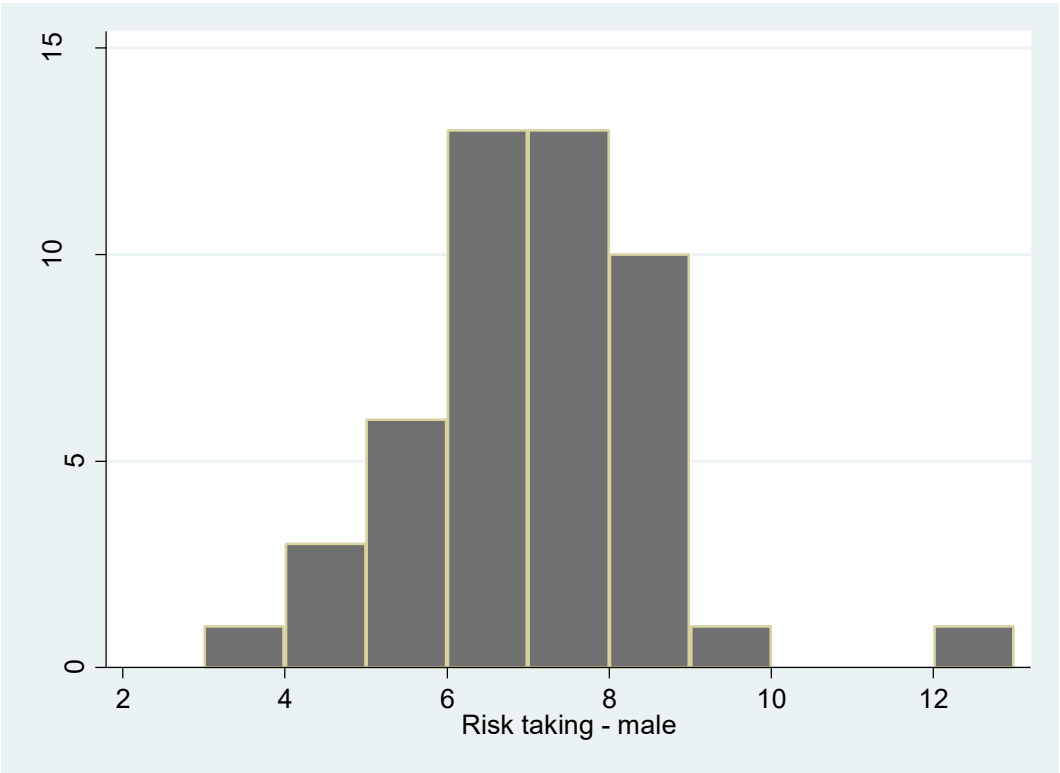
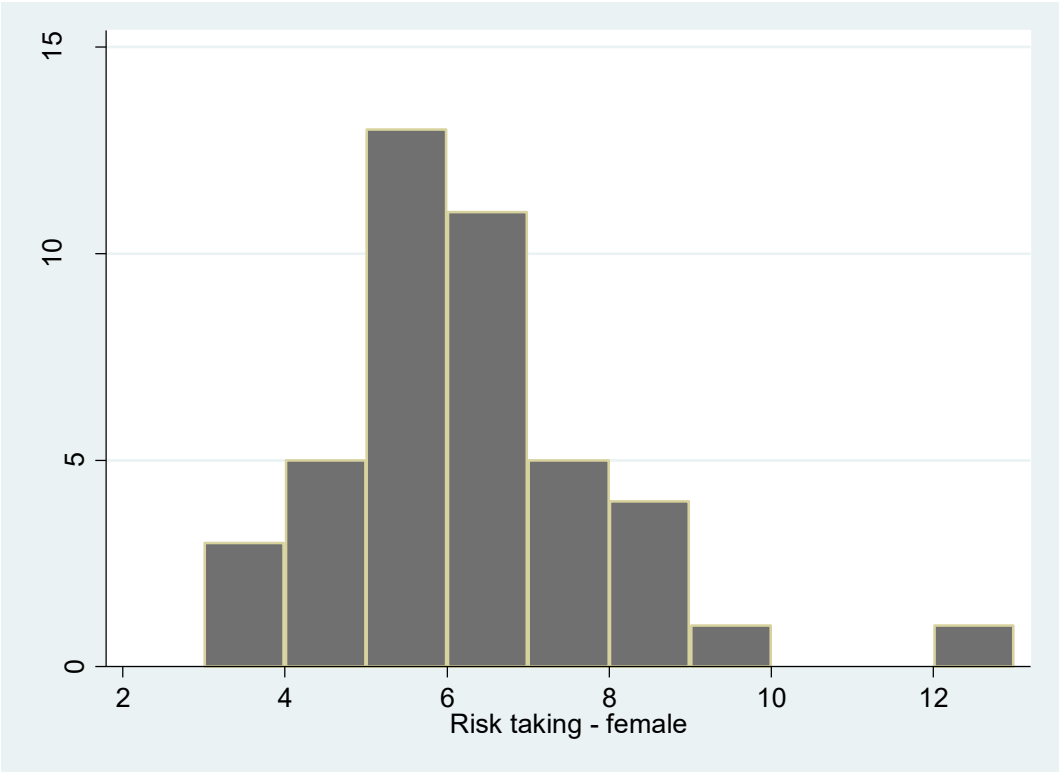
List of Appendices

Appendices

Appendix A: Distribution of participants´ decision on risk taking - male



Appendix B: Distribution of participants´ decision on risk taking - female



Appendix C: Robustness check – all control variables

	Willingness to compete	
	Male	Female
Testosterone	0.066	-0.252*
	(0.090)	(0.148)
Cortisol	-0.645	-0.192
	(0.553)	(0.693)
Math´s task ability	2.068*	1.140
	(1.171)	(1.329)
Anxiety	-0.628	-0.168
	(0.499)	(0.509)
Smoking	-17.940*	-5.897
	(10.500)	(10.70)
Height	-0.837	0.045
	(0.545)	(0.594)
Risk taking	9.656***	5.938**
	(2.888)	(2.225)
N	47	42
R^2	0.425	0.302
F	4.539	2.988

We use OLS regression technique and the regression includes a constant. Robust standard errors are stated in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix D: The Big Five personality traits and competitiveness

	Willingness to compete	
	Male	Female
Testosterone	0.077	-0.237*
	(0.130)	(0.135)
Cortisol	-0.539	-1.007
	(0.710)	(0.768)
Math´s task ability	0.787	0.635
	(1.313)	(1.561)
Openness	-1.836**	0.363
	(0.796)	(0.683)
Conscientiousness	-0.257	1.152
	(0.734)	(0.695)
Extraversion	-0.097	-0.368
	(1.090)	(0.884)
Agreeableness	-0.003	-0.472
	(0.836)	(0.673)
Neuroticism	-1.127	0.157
	(0.949)	(0.754)
N	47	47
R^2	0.198	0.185
F	1.561	1.716

We use OLS regression technique and the regression includes a constant. Robust standard errors are stated in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix E: The Big Five personality traits and risk taking

	Risk taking	
	Male	Female
Testosterone	-0.019	-0.069**
	(0.012)	(0.027)
Cortisol	-0.124	-0.096
	(0.081)	(0.064)
Testosterone*Cortisol	0.001	0.003**
	(0.001)	(0.001)
Openness	-0.003	0.041
	(0.43)	(0.55)
Concienstiousness	-0.062**	-0.0088
	(0.025)	(0.054)
Extraversion	-0.011	0.016
	(0.054)	(0.071)
Agreeableness	-0.022	-0.044
	(0.032)	(0.043)
Neuroticism	-0.097**	-0.057
	(0.044)	(0.050)
N	47	43
R^2	0.201	0.225
F	1.820	2.631

We use OLS regression technique and the regression includes a constant. Robust standard errors are stated in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$