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Faculty of Social Sciences
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BACHELOR THESIS

Risk appetite estimation on financial markets

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

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Prague, May 11, 2013

Signature

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Bibliographic entry

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Abstract

The thesis studies role of risk appetite on financial markets. In theoretical part, author describes a notion of this concept, refers to known methods and describes the role of behavioral economics in treatment of this concept. In practical part, models are constructed to explain influence of selected indices on CDS which proxy for sovereign risk of individual developed and emerging markets. Across the globe, there is found strong common component which can be explained by selected indices. It is also observed that GRAI indicator can play role in case of emerging markets. In case of developed markets, however, this property is missing. Granger causality does not prove relationship of GRAI explanation power in direction to sovereign risk.

JEL Classification	C51, D80, F40 G12, G15
Keywords	risk appetite, risk aversion, sovereign risk, financial markets

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Abstrakt

Tato práce se zabývá rolí sklonu k riziku na finančních trzích. V teoretické části autor popisuje pochopení tohoto pojmu, poukazuje na známé metody a roli behaviorální ekonomie v řešení tohoto problému. V praktické části jsou potom vytvořeny modely vysvětlující vliv vybraných indexů na swapy úvěrového selhání (CDS), které nahrazují měřítko rizika země pro jednotlivé rozvinuté a rozvíjející se trhy. Světově je zjištěn silný společný komponent, který je možno vysvětlit vybranými indexy. Je také pozorováno, že v případě rozvíjejích se trhů může GRAI indikátor hrát roli, avšak pro rozvinuté trhy tato vlastnost chybí. Grangerova kauzalita nepotvrzuje vztah vysvětlující funkce GRAI směrem k rizikovosti daných zemí.

Klasifikace JEL	C51, D80, F40 G12, G15
Klíčová slova	sklon k riziku, averze k riziku, riziko země, finanční trhy

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Acronyms

APT Arbitrage Pricing Theory

ARA Absolute Risk Aversion

CDS Credit Default Swap

CRA Constant Risk Aversion

CAPM Capital Asset Pricing Model

CARA Constant Absolute Risk Aversion

CBOE Chicago Board Options Exchange

CRRA Constant Relative Risk Aversion

EMBI+ The Emerging Market Bond Index Plus

GRAI Global Risk Appetite Index

LCVI JPMorgan Liquidity, Credit, and Volatility Index

PCA Principal Component Analysis

RAI Risk Appetite Index

RRA Relative Risk Aversion

SDF Stochastic Discount Factor

VIX S&P 500 Implied Volatility Index

VDAX DAX Implied Volatility Index

Bachelor Thesis Proposal

Author	Vojtěch Fidler
Supervisor	Doc. PhDr. Adam Geršl, Ph.D.
Proposed topic	Risk appetite estimation on financial markets

Topic characteristics In this work I would like to gather most known and favourite risk appetite estimators. Specific emphasis will be appointed to the class of GRAI indicators. These are the indicators that build on the work of (Kumar and Persaud, 2002). They have been further developed by process of ortogonalization into so called RAI-MI by (Misina, 2003), (Misina, 2006) and further by "normalization-plus" into FGRAI by (Uhlenbrock, 2009) and some others. Other approaches to a risk appetite assessment will be commented, too. The crucial role of risk appetite understanding will be discussed and also some behavioural models of risk perception will be shown in the end.

In my empirical part I would to focus on the role of GRAI estimators in crisis forecasts. Meaningful focus will be also brought onto the question of their role as an independent variable in macro-level models explaining capital flows in appointed countries.

Outline

1. Introduction
2. Main factors identification
3. Other factors
4. Empirical part
5. Conclusion

Core bibliography

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Chapter 1

Introduction

There is plenty of factors that affect asset prices. Except for the particular asset fundamentals, like riskiness, one also has to account for environment in which these assets are traded. Immediate willingness to bear risk or risk appetite is one of these measures when it comes to such an analysis. This provides with many benefits. For example, we can look at the development of market in better dynamic perspective which helps us to resolve impact of environment condition on particular assets. With this tool we can find out causes of several specific and track real culprits of former market disbalances.

The history has brought several approaches of how to measure for these perceptions. However, these measures vary across assumptions and therefore, not surprisingly, their explanations and outcomes are different. This document provides with relevant overview, mostly of those measures which are model-based and mostly used by practitioners. Assumptions are discussed and benefits and limitations are analyzed. Two of the measures are also employed to link risk appetite with sovereign risk proxied by credit default swaps of sovereing bonds. Thirdly, psychological factors are mentioned as this problematic is obviously strongly relevant to human behavior.

The thesis is structured as follows. Chapter 2 serves preliminarily as a broad introduction into the issue. The chapter begins with motivation of this work, provides with overview of risks at financial markets and describes the notion of risk aversion, risk appetite and uncertainty. The main survey is realized in Chapter 3. This part consists of several distinct sections. Firstly, I show simple measurements which serve as a proxy to risk appetite. Secondly, asset pricing is shown as a basis for computing risk aversion. Thirdly, most noted model-based estimations of risk appetite are depicted and the chapter ends with examples of psychological factors related to risk appetite. In Chapter 4, role of risk appetite in explanation of sovereign risk for 31 developed and emerging markets is observed through the methods such as Principal Component Analysis, OLS regression and Granger causality. Chapter 5 then concludes.

Chapter 2

Notion

2.1 Motivation

Asset prices are subject to changes. Up today, various methods have been introduced to provide with explanations for the reasons of these volatilities. Among these systems with wide range of different perspectives, one strand of research is oriented at the models which elucidate these changes with variable demand for risky assets - risk appetite. The period in which this concept came to the minds of economists is in several sources tracked back to 1990s. Dupuy (2009) points on proliferation of literature about risk appetite after Mexican crisis in 1994 when this concept is probable to play big role in emerging markets. Deutsche Bundesbank (2005) describes the evolution of models elucidating financial crises and their fail in anticipation of the crises which even boosted the efforts on improvement of these models.

Why is this particular perspective of investors' risk states worth of considerations? Economy is about trust which takes with itself many features of sentiment. Further, these sentiments arise from essential feelings about both our present state and our future expectations. Elements like, for instance, state of an economy, the actual and future need of consumption, global macroeconomic outlooks - this is just small list of factors which come into investors' minds and force them to reconsider their everyday strategies.

In another point of view, macroeconomic policy makers try to develop such instruments to link them reasonably with common investors' way of thinking, which is, as many authors belive, displayed in the market prices. The appropriate assessment is heavily valuable because it can be quickly observed for suitable steps of policy actions. For example, with appropriate tools, we can look back in history and see the power of these actions through the lens of financial market participants. But the ex-post analysis is not only situation in which we can make a use of these indicators. In one of the most prominent articles, where this topic gains more ground, Kumar & Persaud (2002) use this method to explain for hidden factors of financial contagion, those that cannot be explained by macroeconomic fundamentals. This notion has vast impact on multinational policies. Despite the policy issues, various private institutions also build up their own frameworks to infer risk appetite from market data. The goal here is to offer the analysis to clients and help them decide on their investing strategies such as contrarian or momentum trading (Misina (2003)). Therefore, the most precise estimate of the environment is invaluable in this business.

The another aspect of risk appetite may be observed and is one of the reasons to make a deep immersion into this topic. As it is closely related to human behavior, risk appetite is not unexpectedly probable to vary significantly in certain periods. In times of tension, sudden decline in risk appetite may be so big that consequences of such a drop may result in serious results, like illiquidity problems, buble burts, domino effects, individual defaults, or even sudden triggering of a crisis may occur (Coudert & Gex (2007)). For previous reasons and for the fact, that this phenomenon is relevant to every market participant, common level of risk appetite may also serve as a multiplicator (Uhlenbrock (2009)) of different kinds of pressure.

Lastly but not least, the concept of risk appetite measurement also challenges ability to indetify future crises. If there is success, one may gain simple, yet powerful tool to prevent future disbalances based on available information. However, this step must come after the right understanding of risk appetite concept. This understanding also helps in answering questions like: "Is there any *natural* level of risk appetite?" ,"Are there any factors that correlate with or directly drive risk appetite?" or "Does it count for risk appetite that higher level of it achieves for faster development?". There are many questions like this in the area of research.

2.2 Concepts of risk

Before the discussion about risk aversion and risk appetite, it should be firstly stated what risks are relevant to this topic. In the world, there exist various types of different kinds of risk. This is just logical consequence of the practical life, because daily routine has always been necessarily accompanied by a notion of risk. Such risk can be relevant to the possibility of injury, damage, loss, and other factors and they are dealt with under uncertainty. The economic theory further divides the common understanding of uncertainty in two groups: (i) a non-measurable uncertainty and (ii) a measurable uncertainty, the former known as "Knightian uncertainty" and the latter recognized as a risk. The word "measurable" means that the probability distribution of the events occurence is known. This thesis observes interactions in financial markets and the risk will be therefore connected with the measurable uncertainty, assuming that probability distributions of uncertain events are sufficiently known (except of extreme events) on financial markets.

Table 2.1 and Table 2.2 summarize the most common risks that are relevant to financial markets participants. Informations are taken from author's knowledge and from various sources among which White & Fan (2006) and Vose (2008) dominate. The overview is extensive and it is necessary to note, that some types of risks apply for different agents. For instance, a portfolio manager will be influenced mostly by volatility risk or market risk, whereas an international investor will mostly consider investment risk or liquidity risk.

2.3 Risk aversion

I firstly start with a brief description of risk aversion because discussion about risk appetite gains a lot from this concept. Observation of risk aversion phenomenon was firsty described in 1738 by Daniel Bernoulli, great Swiss mathematician and physicist, founder of hydrodynamics.[1]

The theory of risk aversion derives from "expected utility maximization of a concave utility of wealth function" (Rabin & Thaler (2001)) and is mostly accompanied by following memorable example: in the game of choice between a) 50/50 chances on winning \$100 or nothing, or b) providing with some certainty equivalent, say \$48, a risk-averse participant will choose the latter, whereas

[1]D. Bernoulli introduces beautiful introduction into the problematics: *"Somehow a very poor fellow obtains a lottery ticket that will yield with equal probability either nothing or twenty thousand ducats. Will this man evaluate his chance of winning at ten thousand ducats? Would he not be illadvised to sell this lottery ticket for nine thousand ducats? To me it seems that the answer is in the negative. On the other hand I am inclined to believe that a rich man would be ill-advised to refuse to buy the lottery ticket for nine thousand ducats. If I am not wrong then it seems clear that all men cannot use the same rule to evaluate the gamble."* Bernoulli (1738), translated by Dr. Louise Sommer and Professor Karl Menger in Sommer (1954)

Table 2.1: Risk overview

Family of risk	**Type of risk**	**Description**
Credit risk	Default risk	*The risk that counterparty will not be able or willing to repay its debt.*
	Downgrade risk	*The risk of repayment difficulties for counterparty, stemming from obtaing lower rating.*
	Sovereign risk	*The probability that the particular government of a country will be unwilling or resistant to pay back its obligations.*
Market risk	Commodity risk	*The risk of unexpected shifts in commodity prices.*
	Exchange rate risk	*The risk of sudden repricing of the exchange rates.*
	Equity risk	*The risk of investment depreciation due to unfavourable stock market dynamics.*
	Interest rate risk	*The risk that interest rates will change. This change directly influences investment value.*
Liquidity risk	Market liquidity risk	*The risk that an asset cannot be marketed easily (promptly and at reasonable price) due to market illiquidity.*
	Funding liquidity risk	*The risk that the firm will be unable to meet its funding obligations at reasonable costs.*
Investment risk	Global risk	*Risks of natural, political, social, economic or technical events.*
	Country risk	*Risks associated to administration of a country such as political instability (war, revolution, . . .) risk, government risk (such as tax reforms, monetary reforms or trade restrictions) or risk of social instability. Also risks associated to economy of a country (the price of capital, market risks), financing of a country or cultural risks.*
	Industry risk	*Product nature risks, product markets risks or competitive risks.*
	Enterprise risk	*Operational risks associated with cost of labour, cost of raw materials and other production factors, finance and behavioral risks.*

Source: author based on his own knowledge, White & Fan (2006), Vose (2008) and other minority sources

Table 2.2: Risk overview (cont'd) – other types

Family of risk	**Description**
Volatility risk	*The risk that price of a portfolio varies due to a change in underlying risk.*
Operational risk	*The risk of loss resulting from inadequate or failed internal processes, people and systems, or from external events. (The definition of Basel Comitee.)*
Systemic risk	*Risk of entire system collapse.*
Systematic risk	*The risk inherent to the market as a whole which cannot be diversifiable.*

Source: author based on his own knowledge, White & Fan (2006), Vose (2008) and other minority sources

a risk-loving participant will choose the game. Economists mostly describe investors' risk aversion in terms of coefficients such as Absolute Risk Aversion (ARA) or Relative Risk Aversion (RRA) (named also as Arrow-Pratt coefficients, after their first describers). These measurements are incorporated into various types of utility functions to represent for investor's attitude to risk — either risk-loving, risk-neutral or risk-averse. Their mathematical expression, given utility function $u(x)$ is described as follows (Pratt (194)):

$$ARA = -\frac{u''(x)}{u'(x)}$$

$$RRA = x \cdot ARA = -x\frac{u''(x)}{u'(x)}$$

The concept of risk aversion is also studied by various economic disciplines like behavioral economics or neuroeconomics. Particularly, behavioral economist would probably infer from the example above that the person has incredibly high (unprobably high) risk aversion. By reflecting strict expected utility theory, Rabin & Thaler (2001) show that rejecting 50/50 bet of losing \$100/ gaining \$110 implies turn-down of a 50/50 game of losing \$1000/gaining \$$\infty$! The similar impossible rates of risk aversion have also led to a well-known problem called "the equity premium puzzle" .[2] As one can see, the concept of risk aversion is very narrowly defined (maybe too technical), yields unrealistic implications and does not allow for any other considerations about investors'

[2]For additional information, see Mehra & Prescott (1985). Behavioral economy explains this puzzle with e.g. myopic risk aversion, for more information one can see Rabin & Thaler (2001) and literature therein.

beliefs or the future payoffs. Dupuy (2009) highlights considerations of risk aversion relative stability by assumption since the times of Bernoulli (1738) and mentions experimental studies which do not prove constant risk aversion. Unfortunately, he does not find any study in which risk aversion is proven to be floating across short time.

2.4 Risk appetite

The previous section analyzed technical concept of risk aversion and mentioned it limited function in the last paragraph. This section now describes the approach to risk appetite.

There might immediately occur a rise of a question whether this is not minus risk aversion — then it would be redundant to introduce a new name. What is actual difference between risk appetite and risk aversion? Generally, the reason of this separation from the risk aversion is to make this concept more practical. Misina (2006) notes, that some researchers still see the term risk appetite as a negative of risk aversion, but the concept as a whole is much more embracing.

Generally, there exist two perspectives of this term, called either as

I Built under a "broad" or "narrow" definition (Uhlenbrock (2009))

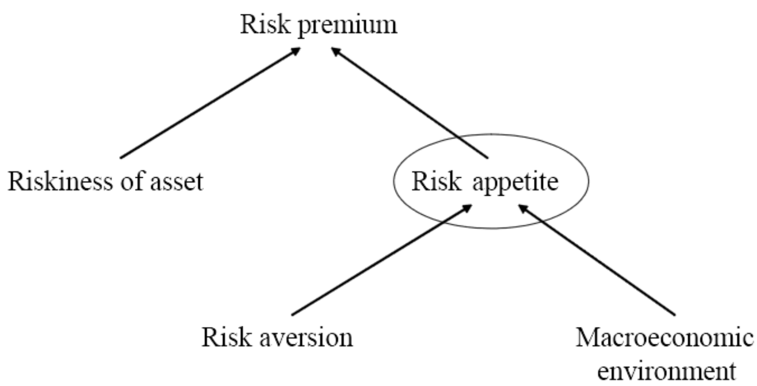
or, equally, as a

II Atheretic or theory-based indexes (Illing & Aaron (2005)).

These two views are very simillar in their sense and the differences between are of therminology character. When thinking of risk appetite in a narrow sense, one usually talks about *investors' average or agregate attitude towards risk* (Uhlenbrock (2009)). Alternative explanation of this term may lie in demand of risky assets or in quantity of risky assets demanded. This is another remark of Misina (2006), but at the same time, he argues that these definitions lead to non-informative statements ignoring the causes of such shifts. Is the demand of either type driven by underlying riskiness, aversion to risk or is it just pure form of attitude to risk (risk appetite)? Clearly, disentangling from other factors is necessary and this is the key characteristic of theory-based indices.

The next methodological step of how to extract the right portion of the sentiments varies in literature. Kumar & Persaud (2002), Misina (2003), Uhlenbrock (2009) and Dupuy (2009) employ rank correlation to indicate moves under risk appetite. On the other hand, authors as Tarashev *et al.* (2003) and Gai & Vause (2006) make use of option-implied volatilites. The interesting approach of Gai & Vause (2006) is depicted in Figure 2.1. The authors consider

Figure 2.1: Risk appetite concept of Gai and Vause (2006)



Source: Gai & Vause (2006)

risk premium as a result of assets riskiness and risk appetite, the latter splitted into effects of risk aversion (for consistency with asset pricing assumed to be constant) and flowing macroeconomic uncertainty. Finally, there also exist some authors (for instance González-Hermosillo (2008)) who understands risk appetite completely differently.

The broad concept of risk appetite can be on the other hand described by effects which reflect relative demand for risky assets Uhlenbrock (2009). For instance, one could infer from rising prices of gold that risk appetite is declining. However, the gold itself does not have to be primary indicator. It may only reflect this phenomenon, but the true reason may lie somewhere else. Such an understanding leads to development of markets indices like JPMorgan Liquidity, Credit, and Volatility Index (LCVI), Merrill Lynch Global Financial Stress Index or State Street Investor Confidence Index. Illing & Aaron (2005) make a short study of these indices present in 2005.[3]

2.5 Problems

Although the practitioners from financial community are aware of existence of volatile risk perceptions, the academics have been firstly rather sceptic to

[3]Understanding of risk appetite applied on micro-level also exists, the discussion however belongs to completely different thesis.

this idea (Misina (2003)). One possible fact might be, that unsatisfactory specification which would be able to bring the concept of risk appetite for an organized discussion makes it problematic. Firstly, discussion must be made about the agents whose risk appetite levels we need to measure and what risks are relevant to our analysis. The overview of these risks was done in Section 2.2. Secondly, what markets do we consider? Is it stock markets or rather credit markets? Or the mix of both? Thirdly, do we intend to measure for investors' appetite for risk globally or rather in specific clusters or even countries? The other questions come in never-ending strand.

According to Misina (2003), two other arguments are in place. Methodologically, assuming for varying risk attitudes is destroying key economic assumption of constant preferences. Second reason is more of practical sense - an equivalence between changes in prices due to both changes in asset riskiness and changing risk aversion was observed. Such observation is very understandable even from simple standpoint. Nevertheless, such equivalence must be splitted into two different parts in order to succesfully measure for the risk appetite. Mostly, this is done through modelling.

From this short overview of challenges, 3 conclusions may be drawn.

- It must be provided for powerful description of risk appetite and relations about markets, type of a risk and areas must be defined.
- The existence of a model is needed to capture safely the role of risk appetite.
- Connection of various types of measurement may be beneficial for final analysis.

Lastly, but not least, it must be emphasized that inferences about attitudes are mostly intangible and may not be verified in 100% of cases. Therefore, it must be provided for good explanation of models along with close relation of results to the reality.

Chapter 3

Survey

3.1 Simple methods

This section serves as an introductory overview of events, market indices and general measures that are in relation to a broad concept of risk appetite. These measures, either single statistics or aggregate indicies, are mostly simple in their methodology and can be derived easily from market data. This fact makes them favorite in financial analysis, modelling and research. However, one has to be focused when dealing with the simple measures, market indices for instance, because their simplicity may also capture another factors.

3.1.1 Safe haven flows

In former sections, one feature of risk appetite was that it is difficult to check for potential measurement error due to the absence of any reliable source of measure, which could provide benchmark for the original computation. However, the data on safe haven flows may be helpful in this task. The common observation is following - during the times of financial turmoil, investors tend to be risk averse and they rebalance their portfolios towards less risky assets. Flight-to-safety or flight-to-liquidity, as these movements are called, provide them with stable source of income in unsteady environment. When it comes to such effects, investors start to demand bonds which are taken as relatively safe (such as U.S. Treasury bills in global or German bunds in Europe). It follows that the higher the demand the higher the price and the lower the yield. The outcomes are able to be captured immediately, which is appreciated by media (Bloomberg (2012)), but the phenomenon is also widely investigated by researchers. Beber *et al.* (2006) disentangle the effects of flight-to-safety and flight-to-liquidity on euro area bond market and find significant role of both credit risk and liquidity, the latter especially important for low credit risk countries and during the market uncertainty. This finding is in compliance with Fontana & Scheicher (2010) who infer important role of flight-to-liquidity from dominating CDS spreads over bond spreads after the fall of Lehman Brothers on 15th September, 2008. The study of Schuknech *et al.* (2010) proves that after this period, the market penalizes much strongly for fiscal imbalances and the pricing is still largely determined by fundamentals. Authors also document the emergence of Germany Bund as a new risk-free asset during the crisis. Finally, De Santis (2012) shows that German Bund was responsible for widening spreads in European countries, even those with solid fiscal fundamentals. Observing the comovement of European sovereign spreads with the ten-year spread between KfW bond and Bund, he finds similarly to Beber *et al.* (2006) strong role of flight-to-safety in direction to German Bund but the role of liquidity is minimal as opposed to both Fontana & Scheicher (2010) and Beber *et al.* (2006).

Yet, the yields of sovereign debt instrument do not have to be the only source of information about the safe haven flows. Several currencies are also considered to maintain the status of safe assets. Historically, this property was attributable to such currencies like Swiss franc, American dollar or Pound sterling. It may be of interest, whether the notion of safe haven currency is more or less attributable to markets or academia. Ranaldo & Söderlind (2007) report, with reference to several authors, that the definition is somewhat unclear. From their research, two definitions step out:

1. The safe haven asset is an asset with low risk and high liquidity which investors purchase during increasing uncertainty.

2. The safe haven asset is an asset which does not comove wth other assets during the financial stress (the so-called *rainy-day asset*, see Kohler (2010)).[1]

The financial media usually cite this movements, but what what may be safe-haven currency for one does not have to to be the same type of currency for others .[2] This source of information is obviously not helpful, but it can be observed that the problem is important for wide range of agents. For instance,

[1]For related literature, see Ranaldo & Söderlind (2007), pg. 4.

[2]the example of completely different peceptions of safe currencies may be obseved by comparing: ICN.com (2013) vs. Money Morning (2011)

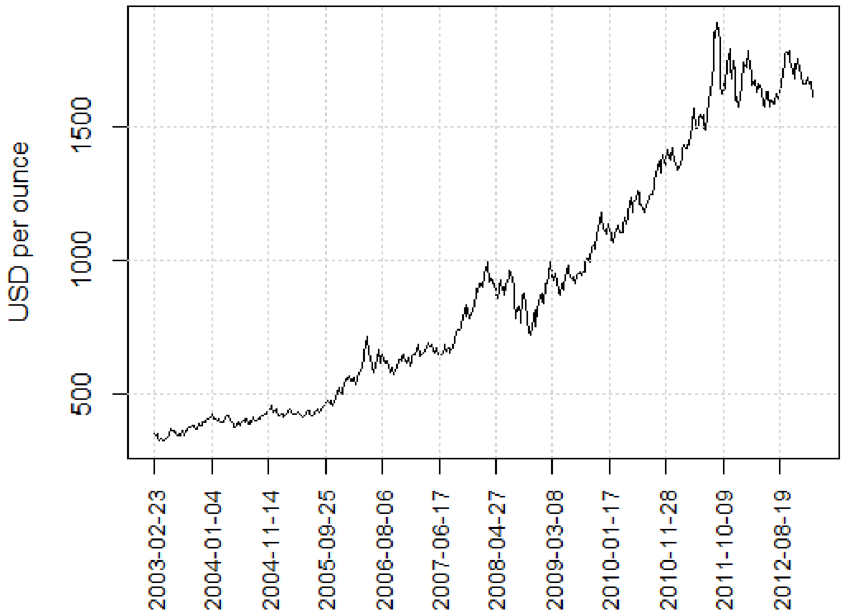
safe-haven flows due to rising risk aversion are closely observed by international traders (Cogliatti).

The outcomes of few studies on this topic are following. Ranaldo & Söderlind (2007) study daily data on Swiss franc, Euro, Japanese yen and Pound sterling versus U.S. dollar. They find evidence on appreciation of these currencies (franc and euro the most) when S&P 500 has negative returns, Treasury notes increase in price and forex markets are unstable. Their outcome is also that these assets tend to behave consistently during whole period. Cairns *et al.* (2007) study instead effects of changes in global currency market volatility and global implied uncertainty (volatility indicators) on volatility of wide set of currencies across globe. They obtained short-term interest rate as single explanatory factor for currency sensitivity. The most "immune" currencies between 2000 and 2006 were Swiss franc, Euro and to some extent Japanese yen, British pound and U.S. dollar. The study of safe haven currencies for recent period of crisis was provided by Kohler (2010). The author studies strong safe haven anti-effects and suggests that repricing of the currencies that were not primarily hit by the crisis is attributable to opposite capital flows and carry trades as a result of growing role of short term interest rate differentials.

Finally, there is a discussion whether gold is a safe haven asset, or not. The reallocation of portfolio in direction to precious metals is possible to make sense in occurence of market uncertainty. The development of gold prices since 2003 is plotted in Figure 3.1. The numbers suggest growing trend of prices from January 2003 to October 2011, where the price has appreciated more than three times of its value from 2005 and more than 4 times of its former value. The prices now fluctuate around $1600 per ounce.

The gold is a measure of risk appetite for some media analysts (The Economist (2012)), Coudert & Gex (2006) and Illing & Aaron (2005) document also using gold price as an indicator of risk appetite among analyses and atheoric indices. But at the same time, the both studies criticize the methodology, as price of gold may simply reflect other variables at the market (like quantity of risk, for example). Further, Baur & Lucey (2010) study prices of gold between 1995-2005 at the markets of U.S., U.K. and Germany with correspondent prices. Although they confirm the gold to be good hedge against stock downturns, the study does not prove the safe haven property for gold in long range. This property was just observed at times of extreme stock market conditions on a basis of days.

Figure 3.1: Gold price in USD



Source: Reuters Wealth Manager

3.1.2 VIX

S&P 500 Implied Volatility Index (VIX) or simply "Volatility Index" is the index constructed by Chicago Board Options Exchange (CBOE) in early 1990s initially to hedge risk. The index measures implied volatility of the S&P 500 return over next 30 days derived from wide range of options quoted at annual basis. Therefore, when one wants to obtain rough 30-day ahead gauge of market fear, the division by $\sqrt{12}$ needs to be executed. Its simple framework can be mathematically described as follows:[3]

$$VIX = 100\sqrt{\frac{365}{30}\sigma^2}$$

, where

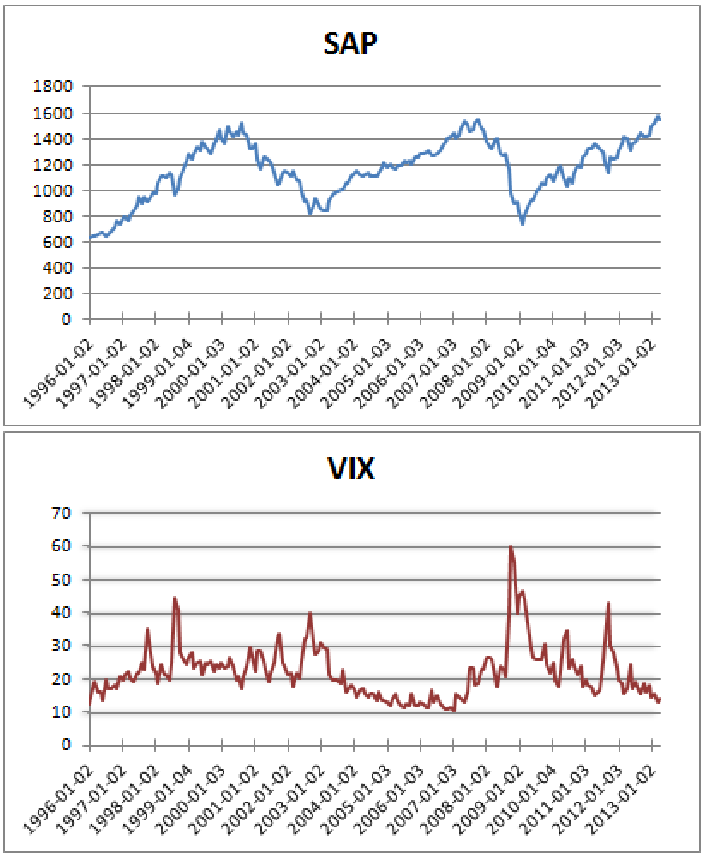
$$\sigma^2 = \sum_{t=1}^{30} \sigma_t^2 \quad .$$

One benefit of such option-implied indices is that they are computed directly from risk-neutral probabilities which implies that the measure provides with unbiased market perceived volatility for the future. The other benefit of

[3] as obtained from: http://cfe.cboe.com/education/vixprimer/About.aspx

VIX is that its simplicity allows for immediate application in the models explaining risk aversion of the market. For example, De Santis (2012) uses VIX together with U.S. credit spread to measure global uncertainty and risk aversion and Arghyrou & Kontonikas (2011) find VIX as an important determinant of European bond spreads during the crisis period. Monthly evolution of VIX and S&P 500 from January 1996 to March 2013 is depicted in Figure 3.2.

Figure 3.2: VIX and S&P 500)



Source: http://finance.yahoo.com

Nevertheless, an ability of index in the original form to gauge pure risk appetite is limited. The reason is that the drift in the index may be simply due to the shift in price of risk and not due to the change of investors' risk aversion, as stated in Coudert & Gex (2006). Therefore, the various methods of extracting the measure from the index have emerged in the literature. To explain movements in Credit Default Swap (CDS) and bond spreads, Fontana & Scheicher (2010) use GARCH-based estimate of volatility from the VIX as an alternative to iTraxx Main Investement Grade index, another possible risk appetite estimator. GARCH estimates of VIX result as siginificant in explaining CDS spreads in this study. Beakert *et al.* (2009) employs dynamic asset pricing, which suggests that latent variables such as risk aversion or economic uncertainty determine asset prices, and extracts the risk aversion from VIX and DAX Implied Volatility Index (VDAX) (the German equivalent to VIX) by controlling for realized volatility (macroeconomic uncertainty). The results find big portion of information about risk aversion in implied volatilities and credit spreads.

3.1.3 Market based indices

During the last decade, plethora of indices have been developed by researchers of private entities to measure financial stress, market sentiment or "risk aversion" "risk appetite"Ṫhese measures, however, mostly do not comply with the theory and are rather heuristically built on common practice. The results logically end up in different outcomes. The reasons are obvious: different choice of markets and instruments, different *perceptions* of risk appetite, various assumptions and implications, ... Studies prove that the measures do not only show different results, but may also contradict in some cases (Illing & Aaron (2005), ECB (2007)). Logically, such inconsistencies are unsatisfactory and confusing and cannot be used for academic purposes unless proven for their solid background. However, this does not mean that they do not cast any inspiration. In fact, there is one index that inspired one research made by IMF.

LCVI is the index developed in 2002 by researchers from J.P. Morgan bank. It is based on equally-weighted three risk factors — liquidity risk, volatility risk and credit risk. Direct approach to the methodical manual from the original authors was not obtained, but there is some other relevant literature which describes this index. Dungey *et al.* (2003) and Illing & Liu (2003) write out 7 measures that indetify each risk. Liquidity risk is represented by 10-y U.S. swap spreads and by U.S. by spread between on-the-run and off-the-run U.S. Treasuries along yield curve. Credit risk is here described by measures of B2-rated spreads of U.S. industrial companies and by The Emerging Market Bond Index Plus (EMBI+). Finally, volatility risk is interpreted as a mix of 12-month turnover-weighted implied volatility of world's 6 major currencies, VIX and Global Risk Appetite Index (GRAI) which takes into account 15 different currencies. The data are transformed into cumulative distribution function without any need of normality assumption. They are further divided to percentiles and the moving average is constructed on a basis of 50 days. Final observations are then compared on a basis of standard deviation. A sudden shift upwards in this index signals an increase in investors' "risk aversion" (equally, decrease in investors' risk appetite).

The magic of this index lies in its ability to describe risk appetite on various markets. The information included in each of its three components may be further developed in more elaborate econometric models and fundamentals of crises may be examined in deep manner. This was approach of Dungey *et al.* (2003) where they examine three major crises form late 90s (Russian debt crisis, LTCM crisis, both in 1998, and speculation on Brazilian Real in 1999) and detect various crisis fundamentals through SVAR analysis. The similiar approach was taken later by the same group of authors and individually by González-Hermosillo (2008) with the method of vector autoregression. The results of these papers trace veins of financial contagion through not only either liquidity, volatility or credit risk but also explain the reasons of a crisis emergence from country-specific risk. Additional important result of González-Hermosillo (2008) is the finding that financial contagion from emerging countries diminishes while global market factors are controlled for.

3.2 Asset pricing theory

Vast amount of academic literature considers modelling as a springboard for risk appetite estimation. There are many reasons for it. Firstly and most importantly, they are meaningful. When one dives into analysis of hidden and abstract concept, solid background is necessary for reliable results. Secondly, they are trackable. The model directly identifies its assumptions which allows for their reverse verification and future discussion. And thirdly, they are elegant and there is large possibility that author who incorporates a suitable model into his or her work may draw up more attention.

One big portion of modelling is made by application of asset pricing with applications of various factor models. In the next section, I provide with derivation of basic models and show several methods which lead to identification of risk appetite concept in its narrower meaning.

3.2.1 Consumption-based model

The standard asset pricing theory (Cochrane (2001) is based on simple economic idea, central for the whole theory. The investors price an asset by discounting the estiamate of future payoff x_{t+1} under the utility U constraints and β as a measure of impatience. Formally:

$$p_t = \mathbb{E}[\beta \frac{u'(c_{t+1})}{u'(c_t)} x_{t+1}] \tag{3.1}$$

Original form of utility function U is two-dimensional and maximised for both actual and future consumption.[4]

$$U(c_t, c_{t+1}) = u(c_t) + \beta \mathbb{E}[u(c_{t+1})]$$

$u'(c_t)$ refers to marginal propensity to consume at time t derived from period utility function $u(\cdot)$ which is increasing and concave in consumption c. Assumption of concavity is based on the fact that a dollar today is not the same as the same dollar tomorrow. One of the reasons is the general uncertainty and a level of risk aversion (for more details about this concept, see Section 2.3).

For simplicity, the Stochastic Discount Factor (SDF) m_{t+1} is introduced:

$$m_{t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)} \cdot x_{t+1}.$$

The Equation 3.1 therefore comes into simpler form

$$p_t = \mathbb{E}(m_{t+1} x_{t+1}) \tag{3.2}$$

or equally, after division by p_t

$$1 = \mathbb{E}(m_{t+1} R_{t+1}) \tag{3.3}$$

where R_{t+1} is gross return of the asset. Consequently, arguments of expected value shall be separated to formalize individual return to asset. From basic property of expected value, one gets

$$1 = \mathbb{E}(m_{t+1}) \cdot \mathbb{E}(R_{t+1}) + cov(m_{t+1}, R_{t+1}), \tag{3.4}$$

[4] In some other forms of utility function the future consumption is ommited and replaced with a measure of wealth like in quadratic value function, or it is completely released as in exponential utility.

because the variables are random.

There shall be defined safe asset which pays known return in every state of the world, good or bad. Therefore it has zero covariance with SDF. This asset is called *risk-free asset* R^f_{t+1}. After making use of this asset in Equation 3.4, we obtain

$$R^f_{t+1} = \frac{1}{\mathbb{E}(m_{t+1})} \tag{3.5}$$

Rearranging Equation 3.5 and plugging into Equation 3.4, we obtain familiar expression:

$$\mathbb{E}(R_{t+1}) - R^f_{t+1} = -R^f_{t+1} cov(m_{t+1}, R_{t+1}). \tag{3.6}$$

In other terms, the risk premium of the asset, expressed on the left side of the equation is defined as risk-free rate times minus the covariance of the return with SDF. The logic of this equation comes from the fact that assets which bring good income in times of high propensity to consume are more valuable compared to assets which bring good income in states of abundance, but deceive in times of need. If we assume that stochastic discount factor volatility is non-zero, Equation 3.5 can be expressed after small extension in a way which provides definition of two single elements which explain variation in risk-premia. These components are quantity of risk ($\beta_{i,m}$) and price of risk (λ_t).

$$\mathbb{E}(R_{t+1}) - R^f_{t+1} = \underbrace{\frac{cov_t(m_{t+1}, R_{t+1})}{var(m_{t+1})}}_{\beta_{i,t}} \underbrace{\frac{-var(m_{t+1})}{\mathbb{E}(m_{t+1})}}_{\lambda_t} \quad . \tag{3.7}$$

But in the same time, the same equation can be expressed in slightly different version by utilizing expression shown in Equation 3.5. This gives

$$\mathbb{E}(R_{t+1}) - R^f_{t+1} = -\underbrace{\frac{cov_t(m_{t+1}, R_{t+1})}{var(m_{t+1})}}_{\beta_{i,t}} \underbrace{var(m_{t+1} R^f_{t+1})}_{\zeta_t} \quad . \tag{3.8}$$

The first equation was used by Dupuy (2009), the second equation comes from the study of Gai & Vause (2006). In both studies, $\beta_{i,t}$ is identified as quantity of risk associated specific to each asset (Gai & Vause (2006)) or equally, contribution of each individual asset to the variance in SDF or asset specific riskiness (Dupuy (2009)). The explanation of the second term λ_t/ζ_t is conditional to the paper methodology. λ_t from Equation 3.7 is very much similar to concept of *discount factor* (Dupuy (2009)) because it contains only information about m_{t+1}. According to its similarity for various types of assets, this factor is here treated as *systemic risk* and is in direct relation to risk appetite. On the other hand, ζ_t in Equation 3.8 is treated as the *unit price of risk* in Gai & Vause (2006) and it is close to an estimate of what investors want to hold in advance. Assuming stable risk-free rate over time, the variation in SDF is what makes it flow. This definition is therefore very close to explanation of variation in risk premia due to SDF volatilities. Gai & Vause (2006) and Coudert & Gex (2007) show that although the inverse of ζ_t is named as *risk aversion*[5], it can be explained using ARA, therefore disentangled from concept of risk aversion according to Capital Asset Pricing Model (CAPM). Assuming power utility function and imposing on stochastic discount factor, SDF is obtained as:

$$m_{t+1} = \delta(\frac{c_{t+1}}{c_t})^{-\gamma}$$

and expected return can be conveniently described by log-normally distributed growth of consumption Δc as

$$\mathbb{E}(R^i) = R^f + \beta_{i,\Delta c}\zeta_{\Delta c} \quad .^6 \tag{3.9}$$

$$\zeta_{\Delta c} = \gamma var(\Delta c) \quad . \tag{3.10}$$

The γ refers to the risk aversion coefficient from the power utility function. Therefore, assuming this structure of SDF, the variance in risk appetite $\zeta_{\Delta c}$ may not be only due to change in *risk aversion* but also to changes in consumption growth - macroeconomic forecasts, generally. As in Gai & Vause (2006), this volatility may incorporate factors such as unemployment prospects, product growth, et cetera.[7]

3.2.2 CAPM

The consistency of previous model with the CAPM was prooved in Coudert & Gex (2007). The market return R^m is proxied for return on wealth portfolio R^W in

$$m_{t+1} = a - bR^W_{t+1}$$

[5]Actually *minus* risk appetite as defined in this work.

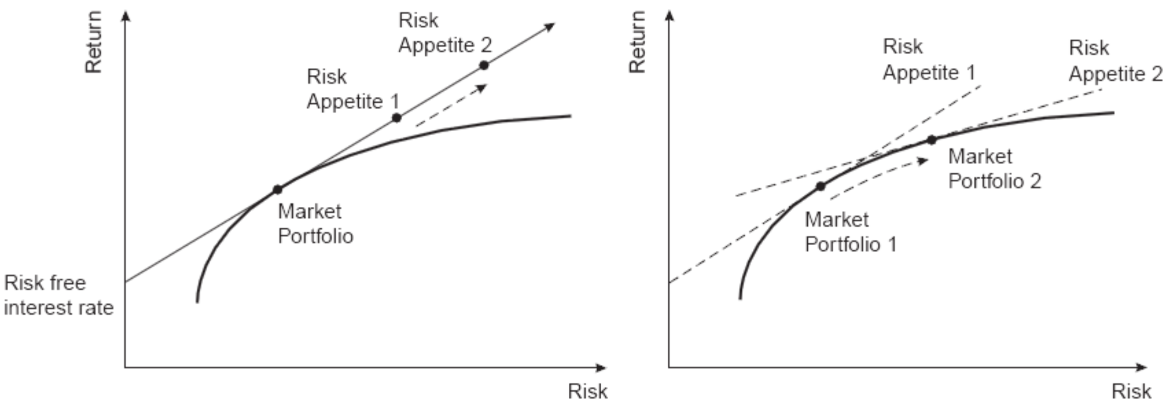
[6]Time horizon is ommited but it should be clear that future payoffs in $t+1$ are still considered.

[7]I skip the description of technological utilization of these models for informatory purposes and show it later in this work.

and the results of enrolling this structure are similar of those from Equation 3.8. Particularly, market return plays similar role as the consumption growth in this equation.

The another explanation using CAPM was embodied in early version of risk appetite estimation. In their prominent article, Kumar & Persaud (2002) utilize CAPM - they however restrict an assumption of a risk free rate, under which investors can infinitely lend, and they add the assumption that *investors share same but changing risk appetite.* Such framework then allows for tranformations of market portfolio in accordance to state of investors' risk perceptions. The comparison in Figure 3.3 shows why such assumption is needed.

Figure 3.3: Standard CAPM vs. Modified CAPM



Source: Kumar & Persaud (2002)

Geometrically, Kumar & Persaud (2002) explain risk appetite as a slope of tangent to the frontier of efficient market portfolios. Mathematically, if such frontier is described by some parabolic function explaining its variance as

$$\sigma_M^2 = \alpha_1 \mu_M^2 + \alpha_2 \mu_M + c \quad , \tag{3.11}$$

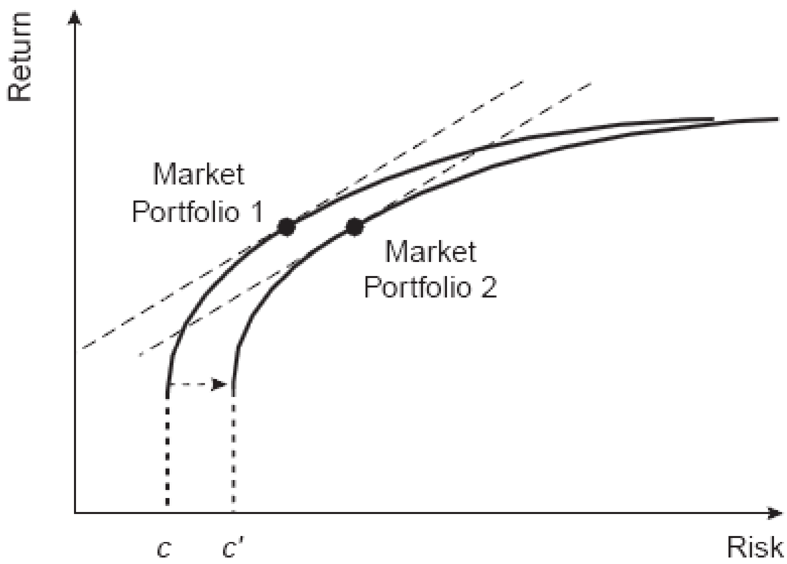
the risk appetite K is described as the slope of this curve at certain point, represented as a derivative

$$K = \frac{\partial K}{\partial \mu} = 2\alpha_1 \mu_M + \alpha_2 \quad .$$

The fact that K is single variable helps in notion that risk appetite is linked to required rate of portfolio return μ_M. If investors' risk appetite rises, they start buying risky assets in such a way, that newly transformed portofolios are riskier but offer higher returns.

On the other hand, the event in which all the assets in market portofolio become riskier does not need to end up in lowering risk appetite. If one considers the situation that riskiness increases in c, the market portfolio moves to the right and risk appetite does not change, since $\partial K/\partial c = 0$. This is shown in Figure 3.4.

Figure 3.4: Increase of general risk



Source: Kumar & Persaud (2002)

Yet, the another version of CAPM was introduced in article of Misina (2003). In this framework, consider representative-agent model who derives her utility from exponential utility from Constant Absolute Risk Aversion (CARA) class of functions

$$u(c) = -e^{-\rho c}.$$

The CAPM model for such an agent has following expression in Cochrane (2001):

$$\mathbb{E}(R^{ex}) = \mathbb{E}(R_i) - R^f = \rho \cdot cov_{(R^M, R_i)} \tag{3.12}$$

In words, the excess return on asset i is determined by the level of risk aversion of particular agent and by the extent of how much the excess return follows the market return R^M. The dynamics of this framework is such, that

$$\frac{\partial \mathbb{E}(R^{ex})}{\partial cov_{(R^M,R_i)}} = \rho \quad ; \quad \frac{\partial \mathbb{E}(R^{ex})}{\partial \rho} = cov_{(R^M,R_i)}$$

and implies that changes in asset riskiness make constant changes in excess return across the portofolio, whereas changes in risk aversion lead to different repricing and make the so-called *rank effect*.[8]

3.2.3 APT

The theory of Arbitrage Pricing Theory (APT) as defined in Cochrane (2001) starts with the fact that stock returns are driven primarily by common components. Furthermore, the assets also move idiosyncratically. This movement however does not incorporate any risk prices because investors diversify their portfolios. Therefore, the price of risk can be traced only to common components which are called *factors*. These factors are observable but cannot be insured by process of arbitrage because of their covariance with the portfolio. The theory does not tell about origin of these components. There is however research on the structure of these factors. For instance, Coudert & Gex (2007) cite notable Fama-French three factor model which explains changes in excess return of US stocks.

The fact that APT is different from other version of asset pricing is in the imposition on SDF such that

$$m_{t+1} = f'_{t+1} b \tag{3.13}$$

, where m_{t+1} is SDF, f'_{t+1} is the vector of factors and b is the vector of factor loadings. The stochastic discount factor m_{t+1} therefore does not have to rely rigidly upon consumption or market returns (Coudert & Gex (2007)) as in other utility functions and the variation of asset prices can be explained by common variables which may be in direct relation to some deterministic factors of risk appetite. This assumption and the assumption that investors hold various portfolios makes this theory very practical.

Although one may choose from different methodologies how to employ APT fremework, there exists simple and straightforward technique called Principal Component Analysis (PCA) (noted inCoudert & Gex (2007)). A survey of former research using this concept can be found in later sections of this work also with the application on global CDS spreads.

[8] Next section provides with detailed description of this term defined by Misina (2003).

3.3 Global Risk Appetite Index

3.3.1 Original version

One of the first attempts to gauge investors' willingness to bear risk was due to phenomenon of financial contagion. The authors from International Monetary Fund Kumar & Persaud (2002) posed a hypothesis that, next to the fundamental contagious channels (e.g. trade links, interest rates), there may also exist some unanticipated, "hidden" factor, which is closely related to investors' behaviour. Furthermore, this transmission channel might serve as a very important factor during crises occurence. Asian crisis and devaluation of Thai baht serve as an example. The rate of capital outflow occured rapidly because of quick reassessment of investors about their positions in the area (Kumar & Persaud (2002)).

Kumar & Persaud (2002) see the risk appetite, next to trade links and common external shock, as one of the most important player in international contagion. This was proven by literature survey from Dungey *et al.* (2003) where 3 distinctive transmission channels were observed according to investors' wealth and willingness to bear risk. These comprise of effect of investors' rebalancing their portfolio, common lender and risk appetite. But Kumar & Persaud (2002) show, that these three factors are also entangled together. For example, problem of rebalancing global portfolio is also related to risk appetite, because when investors's risk appetite in one country rises, they start to sell risky instruments and demand those which are safe. Consequently, the price of risky assets declines and vice versa, which is observed also as a "pure contagion"˙The second problem explains the concept of risk appetite in alternative way and we may relate it also to the global investor from the first problem. If part of his portfolio becomes risky, his risk management policy - which is related to risk appetite - does not allow him demanding other risky assets because of possible liquidity problems. The other name for the common lender is "the common creditor" .

The method of Kumar & Persaud (2002) is CAPM shown in section Subsection 3.2.2. The method which makes this innovative and favorable for risk appetite measurement is the assumption that *investors share common but changing appetite risk.* In comparison to the theory of classic economics which states that investors differ in their willingness to bear risk but these preferences are fixed, unrelated to the state of macroeconomic conditions, authors rather propose that investors share same perceptions which can be shifted on aggreate level. Particularly, this change is done between two contrast levels of attitude: risk loving and risk aversion. In context of this model, depicted more clearly by Equation 3.11 and Equation 3.12 with their consequent dynamics, the sudden decline of risk appetite is recognized as an increase in risk premiums of all assets in portfolio by respective ammount of their covariance with required return (i.e. asset riskiness). Therefore, premium of riskier asset increases more than premium of safer one due to proportionality.

For this reason, Kumar and Persaud advise to focus more on the *order* of past riskiness and measure it with rank correlation against the order of past returns. During the shift of risk appetite, the riskiest asset in the portfolio is impacted the most and vice versa, and ranks of returns vs. risk do not change. On the other hand, when excess return is related rather to particular assets' riskiness, as in Figure 3.4 (i.e. this change is not driven by common factor) then an event of such a linear push is not probable to be observed and the rank of excess returns is rearranged without any direct link to the order of past riskiness. Assumed further that excess returns are independently distributed and there is zero correlation with past information, we can measure for statistical significance of such correlation.

The Spearman's correlation was analysed by authors to be most suitable for this purpose, because it assigns greater weight to values on tails. In the middle, measurement problems may occur due to either computation mismatch or small scale and the final number would be biased (Kumar & Persaud (2002)). The hypothesis that a sudden shift in risk appetite will result in equal shift in premium demanded according to previous riskiness makes this index very intuitive. The following subsections show the evolution of this concept.

3.3.2 Extensions of GRAI

The previous system of risk appetite assessment is one of the first attemps of mapping the pattern. However, it is not clear whether such approach of rather hypothetical manner is able to be interpreted from theoretical perspective. This is goal of Misina (2003). In his paper he provides with modelled version of the index and observes several assumptions which are necessary to be stated while using this index. Finally, he informs about circumstances in which is this type of measurement plausible.

Misina (2003) states that it is very important to break so-called “observational equivalence” . The observational equivalence is a notion that one cannot simply trace the causes of shifting asset prices to riskiness, or risk aversion respectivelly, by just observation — the effects of the rebalancing are the same because there is observed direct move to the less risky assets if any of these instances occurs, so the only solution is disentangling these phenomena. To prepare a solid background, two propositions have to be imposed.[9]

Proposition 3.1. *A change in investors' risk aversion will have monotonic effects on assets in different risk classes: the impact on returns will depend on the riskiness of a particular asset.*

When it comes to decreasing risk appetite, the excess returns will be higher for less risky assets and vice versa. Formally, rank effect will occur.

Definition 3.1 (Rank effect). We define **rank effect** as event when

$$\sigma_j > \sigma_l \Rightarrow \Delta R_j^{ex} > \Delta R_l^{ex}, \forall j > l$$

$$\sigma_j < \sigma_l \Rightarrow \Delta R_j^{ex} < \Delta R_l^{ex}, \forall j < l$$

where we refer to σ_k as to riskiness of k-th asset and to R_k^{ex} as to its excess return.

The Proposition 3.1 is insufficent because incorporation for riskiness is needed. Therefore, the second proposition is introduced.

Proposition 3.2. *A change in the riskiness of an asset will not have monotonic effects on excess returns across different asset classes. The impact on returns will not depend on the riskiness of a particular asset.* [10]

Then it can be statistically tested for significance of rank correlation using previous propositions.

The key finding of Misina (2003) lies in notion that GRAI indicator is also subject to several assumptions. Consider now Equation 3.12 with respect to portfolio adjustments. If a certain asset i has a certain proportion in portfolio α_i then R^M can be written as

[9] Although without explicit stating, they were already part of Kumar & Persaud (2002). Version of the propositions statements is taken directly from Misina (2003).

[10] Assumed that investors' risk aversion is exogenous and constant.

$$R^m = \sum_{i=1}^{N} \alpha_i R_i, \sum_{i=1}^{N} \alpha_i = 1 \quad . \tag{3.14}$$

In the same way, the covariance of market portfolio with i-th asset is written as

$$cov_{(R^M,R_i)} = \sigma_{i,M} = \sum_{i=1}^{N} \alpha_i \sigma_{i,k} = \alpha_i \sigma_i^2 + \sum_{i \neq k}^{N} \alpha_i \sigma_{i,k} \quad . \tag{3.15}$$

After this, the dynamics may be further extended as following

$$d\mathbb{E}(R_i^{ex}) = \frac{\partial \mathbb{E}(R_i^{ex})}{\partial \rho} \Delta\rho + \frac{\partial \mathbb{E}(R_i^{ex})}{\partial \sigma_i^2} \Delta\sigma_i^2 + \sum_{i \neq k}^{N} \frac{\partial \mathbb{E}(R_i^{ex})}{\partial \sigma_{i,k}} \Delta\sigma_{i,k} \tag{3.16}$$

The changes in excess return can be now traced not only to changes in risk aversion and underlying risk, but also to changes in cross-correlations with other assets. The latter statement means that the price of an asset may be affected also by change in the riskiness of the other assets. This obviously deteriorates the model because it is now permitted for an asset k to be influenced by change in riskiness of another asset(s) $i \neq k$ (and respectively). For this fact, a technique of orthogonalization is suggested in Misina (2006). The rationale behind it simply states that from some n-dimensional matrix we can obtain n orthogonal vectors (factors) and provide for satisfaction of zero cross-correlation assumption. The last term in Equation 3.16 is then equal to zero.

Conduction of this approach however brings up a new problem — the eigenvectors developed by orthogonalization are not unique. Particularly, when u is eigenvector of a matrix M, then for any λ such that $\lambda \in \mathbb{C}\backslash\{0\}$, λu is also eigenvector of M Kalenda *et al.* (2006). Normalization of the vectors is then then suggested by Misina (2006) to interpret each asset as being represented by proportional weight. Revision of this method was conducted by Uhlenbrock (2009). Findings of this revision state that the single restriction of normalization does not yield straightforward uniqeness. In fact, only restriction imposed is such that squared elements of normalised eigenvectored need to sum up to unity. Multiplication of each element of vector by -1 brings the same outcomes and assumption of uniqeness is broken. Uhlenbrock (2009) therefore suggests for "normalisation-plus " restricition which states that sum of elements in each eigenvector must be non-negative.

3.3.3 Variations of GRAI

Being relatively simple to explain and compute, several authors tend to modify GRAI indicator for the sake of their own methodology. This approach leads to several new applications of the original GRAI methodology, showing the benefit from wide range of possibilites it offers. Variations are implemented mostly on two areas.

Data Although the GRAI was originally applied on currency markets, researchers include also the panel data from credit or stock markets (Uhlenbrock (2009)) or even their joint cross-sections (Deutsche Bundesbank (2005)). The benefit of using currency markets in the dataset is advocated in Kumar & Persaud (2002) by extensive literature, liquidity, magnitude of data and promptness in reflecting effects of contagion (recall that their paper focuses on the role of risk appetite on contagion). However, using the data from foreign exchange may also bring some difficulties. For instance, the data may be limited because of orientation on certain geographic area (such as widespread of Euro currency in Europe). The data are then possible to be significantly biased. The other issues may come with the information reflected by currency market. On the other hand, stock data bring many comparable instruments with a lot of information considering real economy (Uhlenbrock (2009)).

Type of correlation There are some variations that employ linear correlation, rather than rank correlation proposed by original method. This linear correlation is mostly obtained as a slope coefficient in regression explaing effects of volatility on asset performance. Coudert & Gex (2006) report that these indices are then called Risk Appetite Index (RAI). Deutsche Bundesbank (2005) use such a methodology in regression of excess returns on volatility and changes in issuer's rating, the slope coefficient at the volatility variable is then taken as a measure of risk appetite.

3.4 Option-implied risk appetite

In this section, I provide with another detailed version of how to describe investors' willingness to take risks. This construction, similarly to previous one, builds on asset pricing modelling. However, it abandons CAPM and restricts to simple consumption-based versions. There is already a description in Subsection 3.2.1 of how the models are constructed. This section comments on the utilizing of these models in the constructions of risk appetite oriented at implied probabilities of investors from option instruments.

Particularly, the decomposition in Equation 3.7 and Equation 3.8 leads to notion that the amount of premium is brought from both quantity of risk (β_i) and price of risk (λ_t/ζ_t) which is common across all assets. In the version of Gai & Vause (2006) which is described first, the risk appetite is computed as the inverse of price of the risk, ζ_t. Because of variation in stochastic factor m_{t+1}, which tells about variation in uncertainty, the ratio is dependent on degree of this uncertainty about future consumption and on factors that determine its overall level. The degree of the second uncertainty can be refered to as the degree of risk aversion which reflects agents' utility preferences (see Equation 3.10). These are assumed to be stable over time as recognized by Gai & Vause (2006).[11]

The notion that the risk appetite is linked to investors' beliefs about future states of the world proves to be helpful in the moment when the ζ_t needs to be constructed. Gai & Vause (2006) show that for S states of the world, we have

$$1 = \mathbb{E}(m_{t+1} \cdot R_{t+1}) = \sum_{s=1}^{S} m_{t+1}(s) \cdot R_{t+1}(s) \cdot p_{t+1}(s) \tag{3.17}$$

where $p_{t+1}(s)$ is investor's subjective probability about particular state s, and for risk-neutral probabilities discounted with risk-free rate, we similarly obtain

$$1 = \mathbb{E}(m_{t+1} \cdot R_{t+1}) = \sum_{s=1}^{S} \frac{1}{R^f_{t+1}} \cdot R_{t+1}(s) \cdot p^*_{t+1}(s) \tag{3.18}$$

Joining these two previous equations together,

$$m_{t+1}(s) = \frac{1}{R^f_{t+1}} \cdot \frac{p^*_{t+1}(s)}{p_{t+1}(s)} \tag{3.19}$$

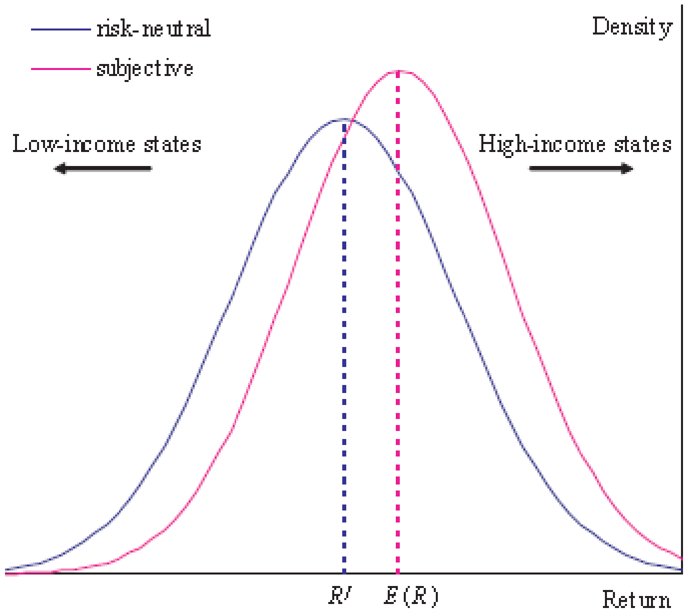
and plugging this expression into Equation 3.8, more detailed formula describing (ζ_t) is provided.

$$\zeta_t = var\left(\frac{p^*_{t+1}(s)}{p_{t+1}(s)}\right) \cdot \frac{1}{R^f_{t+1}} \tag{3.20}$$

[11] "One would expect that the periodic shifts in market sentiment witnessed over time are more likely to be driven by the macroeconomic environment rather than by changes in the risk aversion of investors." Gai & Vause (2006)

The risk appetite is now determined by the second moment of the ratio of probability distributions and by the return on the risk-free asset. As it was mentioned earlier, to comply with the concept, the inverse of ζ_t must be taken. It follows that in this framework, either frequent movements in the ratio of risk-neutral vs. subjective probabilities or significantly low levels of risk-free rate will project into the declines of the risk appetite. Figure 3.5 describes relationship between two hypothetical probability distributions.

Figure 3.5: Probabilities distribution – Gai & Vause (2006)



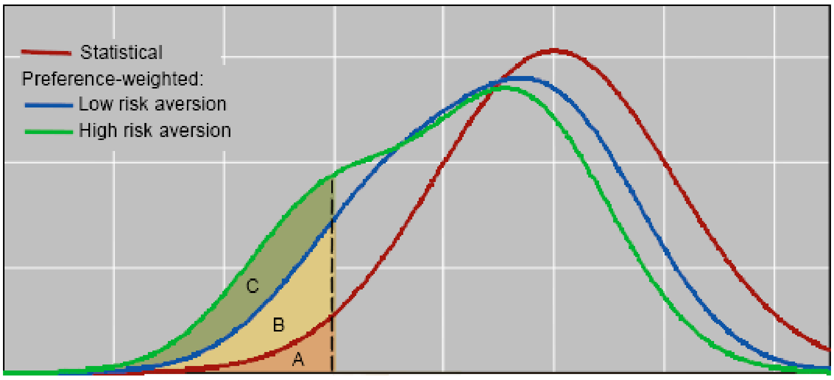
Source: Gai & Vause (2006)

A similar approach is taken by the group of authors from the Bank for International Settlements in Tarashev *et al.* (2003). The authors however argue only with the conviction that simply the ratio of the probabilites is sufficient [12] and they compute areas under the distribution curves for comparison (see Figure 3.6). This methodology is criticized in Gai & Vause (2006) suggesting, that the ratio may also reflect other factors as it is related to the marginal utility of consumption.

As it can be seen, the risk appetite indices constructed on a modeled basis of future outlooks are very simple and sustainable. But they have also their

[12] Besides the same construction of the risk-neutral probability distribution is the statistical distribution reflecting the option's historical performance taken as a construct for subjective probability.

Figure 3.6: Probabilities distribution – Tarashev *et al.* (2003)



Source: Tarashev *et al.* (2003)

drawbacks. Despite the complexity of technical part, the access to data may be also problem for example when one intends to compute risk appetite for emerging markets as in Chen & Poon (2007). The fact that some analyses require frequent measures is even more challenging.

3.5 Principal Component Analysis

This section follows Subsection 3.2.3 which discussed briefly the role of APT in risk appetite estimation and mentioned PCA as the methodology leading to indetification of commonalities. The PCA is described closely in this section. The outcome of this method is following: by application to a large dataset, the PCA will produce an ordered set of orthogonal coordinates (components) which describe this dataset the most, according to its variance. The first component brings most contribution for explanation of total variance, the second one brings additionally the second most contribution et cetera. In fact, the principal components are eigenvectors of correlation matrix and serve as weights. By interconnection with observed data, they bring newly transformed matrix. The interesting property is that summation of the eigenvalues gives total variance which may be used to explain contribution of a selected factor to total variance.

The choice of principal components to approximate the dataset is discretionary. However, one should choose as much factors as needed to keep the model simple and explanatory in the same time. According to Coudert & Gex (2007), there are two criteria which are mostly used:

- the **Joliffe criterion** under which the factors explaining over 80% in addition are omitted
- the **Kaiser criterion** which allows only for the factors (eigenvectors) computed by eigenvalues over 1.

To show an example, this method is used in study of McGuire & Schrijvers (2003). The authors study similarities in credit spreads of 15 emerging countries. Their analysis suggests that one third of the spread volatility can be assigned to common factor while remaining 67% of volatility is subject to idiosyncracy. Among many findings, the common factor in the sample is to be positively correlated with VIX and high-yield spread and negatively correlated with US interest rates. The authors conclude that common variation in emerging market sovereign spreads is highly due to the factors of risk appetite.

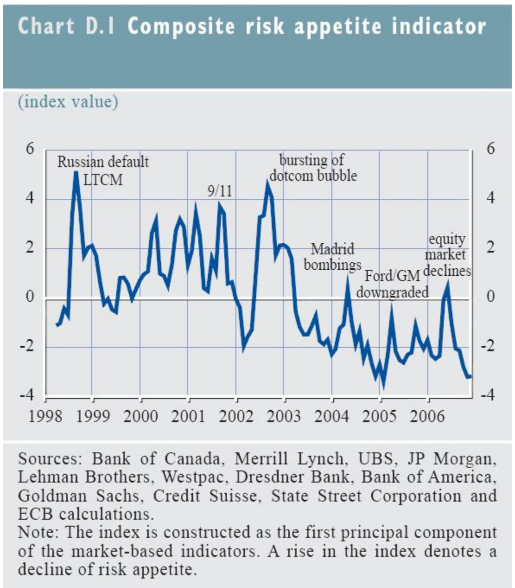
In another study, Slok & Kennedy (2004), the larger dataset of implied equity premiums, corporate bond spreads and emerging bond spreads is examined for period from 1998 to 2004. The reason to study such a large portfolio is motivated by common fall of risk premia of these assets, starting in 2002 and continuing to 2004. Two significant common factors were analyzed and on average 45% of uniqeness was estimated (slightly better result than in previous study). Furthermore, these factors were found to cooperate significatnly with OECD's leading indicator of industrial production and various measures of global liquidity. [13]

In ECB (2007) the PCA was used in different, yet interesting way. When observing proliferation of "risk appetite " indices based on market observations, one might expect some commonality to occur among them despite the existence of different results. In this paper, the method of PCA was applied on 14 different risk measures for period from February 1999 to July 2004. Five (six) significant common factors under Kaiser (Joliffe) criterion were found as underlying possibly reflecting different methodologies of each group of indices. Under analysis of two groups of indices, model-based versus market-oriented, the latter is found to contain slightly higher portion of commonality in the first factor against the second, compared to former (47% and 26% for market-oriented vs. 35% and 30% for theory). The composite risk index based on

[13]Detrended GDP-weighted M3 of 3 largest economies was taken as a proxy for global liquidty was shown to bring best results. Alternative proxy, measuring by GDP-weighted interest rates, has been seen insignificant. One of the reasons may be that interest rates were stable during the period in comparison to higly unstable risk premia (Slok & Kennedy (2004)).

first principal component has been developed and, suprisingly, its levels seem to be corresponding with major events of the period under examination (see Figure 3.7).

Figure 3.7: ECB Composite Risk Appetite Index



Source: ECB (2007)

3.6 Psychological models

As the matter of risk aversion and appetite is in relation with investors' attitudes, there are some studies which extend the research with the findings of behavioral economics & finance and other psychological factors. The risk aversion known by ARA and RRA coefficients is often assumed to be stable. This property, however, is not with the assumption that investors' switch their risk appetite regimes (risk attitudes). Such an explanatory dichotomy is studied in Misina (2005) and the concept of implied risk aversion is proposed to explain effects of optimism and pessimism on the asset prices. Investors review their outlooks according to historical performance and assign higher probability to the good or bad states. This revision contains information on expected payoff along with a new level of utility. To bring an agent back to her previous level of utility under the expected payoff, equivalent variation EV is introduced such that

$$\rho_l = \rho + EV$$

, where ρ is the original risk aversion level, and ρ_l is new risk aversion *implied* by the agent. This method simulates periods of changing perceptions and helps to understand bull and bear markets.

Rabin & Thaler (2001) critize expected utility theory because of the fact that risk aversion concept should be much broader in reality than just a product of it. The authors identify two concepts that can enhance "true" risk aversion: loss aversion and mental accounting. The first comes from the prospect theory and states that individuals put more weight on losses than on gains. The second comes from the observation that individuals and households often treat risk in a narrow spectrum. Rejections of small-scale better-than-fair games may be an example of the latter.

Finally for the case of financial markets, Baker & Wurgler (2007) name two central assumptions of behavioral finance (investors are subject to sentiment and there are limits to arbitrage) and they introduce several factors which are possible to be in relationship with investor sentiment.[14] These measurements comprise one big set containing investor surveys, operations of mutual funds, trading volumes, dividend premia, IPO returns/volumes or psychological factors like trades of unexperienced investors or investor moods.

[14]Also known as market sentiment, which can be another name for similar concept as risk appetite in broad meaning (Misina (2006)). These names are typical for papers studying the problem from psychological perspective.

Chapter 4

Empirical analysis

In previous sections, the concept of risk appetite was discussed in the broad spectrum. The survey suggests, that it is typically demanding to obtain single reliable measure to fit every market. In advance, the measures differ in both assumptions and results. Despite the challenge, these measures may be useful, because the phenomenon of investor's attitudes is closely attributive to other-than-fundamental driven developments in asset prices. If this is true, then how much do these hidden paths play role?

In this chapter, I observe daily effects of global risk appetite on the evolution of sovereign risk measured by ten-year sovereign CDS. Credit markets have gone through big unprecedent repricing from September 2007 (Fontana & Scheicher (2010)) and these effects came into sovereign markets as the global financial crisis transformed into sovereign debt crisis (Lešanovská *et al.* (2013)), particularly since September 2008 (Fontana & Scheicher (2010)). This chapter investigates whether in last four years, when markets focused on evolution of sovereign risk, the role of global risk appetite has been present.

4.1 The Model

4.1.1 Methodology

The analysis comprises of three blocks. In the first part, Principal Component Analysis is employed to identify common factors in sovereign risk determination. As a proxy to sovereign risk, daily data of 10-year sovereign CDS are used. First two principal components are then chosen and regressed on the risk appetite indices to prove whether the global movement in sovereign CDS is due to risk aversion. The regression is made for GRAI and VIX separately:

$$GRAI_t = \phi_0 + \phi_1 pc1_{i,t,t-1} + \phi_2 pc2_{i,t,t-1}$$

$$\Delta VIX_{t,t-1} = \phi_0 + \phi_1 pc1_{i,t,t-1} + \phi_2 pc2_{i,t,t-1}$$

where pc1 and pc2 are first-differences of first and second principal component, and i corresponds to the selected group of countries (Global, Europe, Asia, Latin America).

In the second part, simple econometric analysis is conducted. The CDS of individual countries are regressed on the global risk-free rate proxied by ten-year U.S. Treasury bonds and on GRAI to find a relationship between risk appetite and sovereign risk. The countries for which the risk appetite is significant will then be identified as prone to investors' attitudes. The model is standard OLS and its framework is depicted followingly:

$$\Delta CDS_{t,t-1} = \beta_0 + \beta_1 GRAI_t + \beta_2 \Delta Tbonds_{t,t-1}$$

First-differencing of both CDS and Tbonds was done. This was due to two factors. One, CDS were found to violate stationarity assumptions and two, to stick with GRAI, because it reflects *changing investors' risk appetite* by definition.

Correlation of course does not imply causation. Therefore, the third part observes this type of relationship through the concept of Granger causality. Granger causality is focused on a question whether scalar y can help forecast scalar x. If it cannot, then y does not Granger-cause x. Mathematically, suppose we have an unrestricted model:

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \cdots + \alpha_l y_{t-l} \tag{4.1}$$

and a restricted model:

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots + \alpha_l x_{t-l} \tag{4.2}$$

and both models are estimated by OLS. If further RSS_u and RSS_r are residual sum of squares from unrestricted and restricted model respectively, then the statistic S has an exact F distribution.

$$S = \frac{(RSS_u - RSS_r)/l}{RSS_l/(T - 2l - 1)}$$

Hamilton (1994) describes this method and notes, that the test is valid only asymptoticaly. Therefore, the other type of test is promoted. This test has a form of $S_2 = \frac{T(RSS_u - RSS_r)}{RSS_r}$ and is distributed under $\chi^2(l)$ distribution. The observation of the relationship between the two statistics was made for the sake of our analysis and it was found that the two statistics have almost identical pdfs for lag $l = 1$. In case of lag $l = 2$, the $\chi^2(l)$ statistic starts to be significant for an F statistic $S = 6$ on 5% level. The R software which is used in this analysis computes only the F statistics and the analysis is therefore oriented only on lags $l = 1, 2$.

The interpretation of Granger-causality is also an important topic. Hamilton (1994) shows that the true causality does not have to be in the same direction with the Granger-causality. The best interpretation of Granger-causality should be rather based on statements about prediction power of one series in direction to another (e.g. whether x helps forecast y or vice versa). The analysis is conducted on every country in the dataset, but the countries for which risk appetite came out as a significant determinant in the second part are emphasized.

4.1.2 Former research

The PCA and factor analysis is commonly used to extract the information about risk aversion (for related literature, see Coudert & Gex (2007)). McGuire & Schrijvers (2003) employ factor analysis in their study of 15 emerging markets across globe and find a single common factor driving the common variation in the bond spreads. This factor, however, explains only one third of the total variation which implies strong role of idiosyncracy in the evolution of bond spreads. The correlation coefficient above 0.4 was found between this factor and both VIX and high-yield spread. Slok & Kennedy (2004) find principal components driving returns among different types of assets in global markets and similarly to McGuire & Schrijvers (2003) regress them on sets of variables (index of production and proxy of liquidity). In case of CDS, Fontana & Scheicher (2010), who study relationship between European sovereign CDS and bond spreads, find that after the fall of Lehman Brothers in 15 September 2008, the role of first common factor has increased from proportion of total variance of 72.6% up to 84.5%.

The role of risk appetite as a part has been studied in Fontana & Scheicher (2010). The proxy is computed as a GARCH-based estimate of volatility from the VIX and found significant for the crisis period. Also De Santis (2012) studies a role of VIX as a measure of risk aversion.

4.1.3 Hypotheses

Based on former research and basic economic intuition, I have set up a list of hypotheses which are to be tested in the following analysis.

1. We expect significant principal component in CDS spreads evolution.
2. Risk appetite is in association with principal components.
3. Risk appetite is not expected to play significant role in developed markets.
4. Risk appetite is expected to play significant role in emerging markets.
5. Risk appetite Granger-causes CDS spreads.

In addition, Table 4.1 describes the expected signs from the econometric model. Both coefficients from the model are expected to be negative. These

Table 4.1: Sign expectation

Name	**Definition**	**Sign**
GRAI	Global risk appetite computed from MSCI indexes	(-)
Tbonds	10-year Treasury bonds	(-)

expectations are based on basic economic intuition about GRAI and T-bonds and on Fontana & Scheicher (2010) who also obtain negative sign for T-bonds.

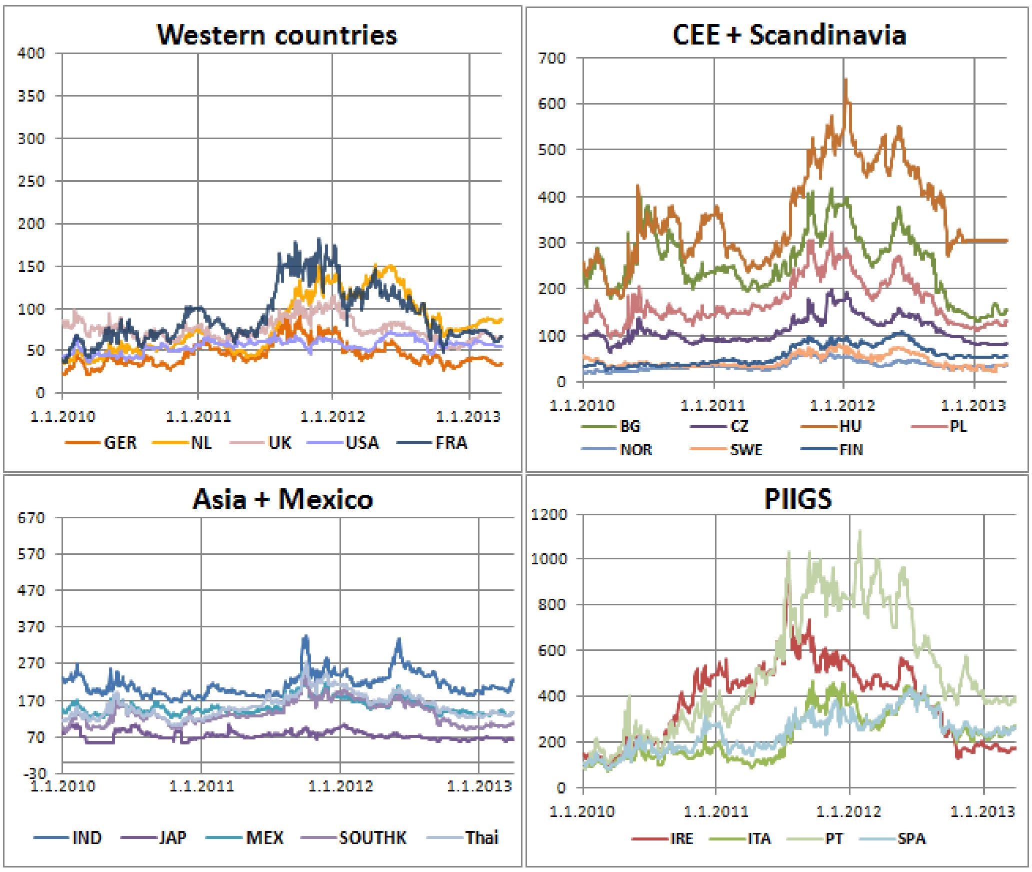
4.2 Data description

4.2.1 CDS

CDS are credit contracts which transfer the risk of credit event from a buyer to a seller. The agreement between two parties is conducted in a way that the buyer of the CDS contract makes payments to the seller (insurer) on a regular basis. The seller, on the other hand, agrees to compensate the buyer in terms of recovery rate of a notional in case a credit event occurs on the side of reference entity. The payments to the insurer are made on regular basis, determined by underlying spread of the CDS contract times the notional. Although initially intended for hedging risk, the CDS contracts also allow for speculation.

Fontana & Scheicher (2010) note that investors use sovereign CDS mainly as trading instruments and use them for these purposes: speculation, hedging country risk, relative-value trading and arbitrage trading. The sovereign CDS spread may therefore be viewed as a good market indicator of sovereign risk (see study of Lešanovská *et al.* (2013) who uses such a proxy). CDS contracts are standardized by International Swaps and Derivative Association and are traded over-the-counter. The trades can be also conducted on baskets of CDS (e.g. Markit iTraxx indices, CDX indices).

Figure 4.1: Examples of CDS spreads. selected groups of countries



Source: Datastream

The importance of the CDS rose in recent financial crisis as the risk of credit events spread around the globe, firstly on institution level, later the risk transmitted to sovereigns as the debt burden realocated. Figure 4.1 shows the evolution of CDS spreads from the beginning of 2010. It can be seen that CDS comove strongly across the globe but this comovement is further intensified by selection of a specified set. For example, a strong comovement is observed for set of chosen so-called Western countries. The similar comovement is observed also for countries of Central and Eastern Europe, but in more volatile manner. Nordic countries are incuded to see a particular diversity between these two groups. Asian countries are observed to show also intensive comovement, but in slightly different manner, than in case of Europe. Finally, a specific set of countries are the ones so called PIIGS countries. These are the European sovereigns (Portugal, Italy, Ireland, Greece and Spain) that have come through problems with financial instability during financial crisis. Their riskiness, the spreads on their CDS, has therefore increased dramatically. Generally, there is significant increase in spreads of European sovereigns in mid-2011 which however does not count for Asian countries. This pattern might be likely relevant to growing uncertainty about Greek future, as second bailout has been discussed since July 2011 to February 2012. From last quarter of 2012 it seems that the levels CDS spread are returning to its previous levels.

For the analysis, a mix of daily 10-year CDS spreads of both developed and emerging countries was chosen. The countries are listed in Table 4.2. The data were obtained from Datastream for time period from January 2009 to March 2013.[1]

4.2.2 GRAI

The GRAI was described in detail in Section 3.3. To compute the index I use daily data of MSCI Global Equity Indices. The indices provide for equity market coverage of 70 Developed, Emerging and Frontier markets. The similar approach was used in Uhlenbrock (2009) who applies the variation of extended method of Misina (2003). The GRAI in this case is computed in pure form and takes the data from 22 most capitalized markets according to World Bank.[2] For computation, rank correlation between 12 week log returns and one year

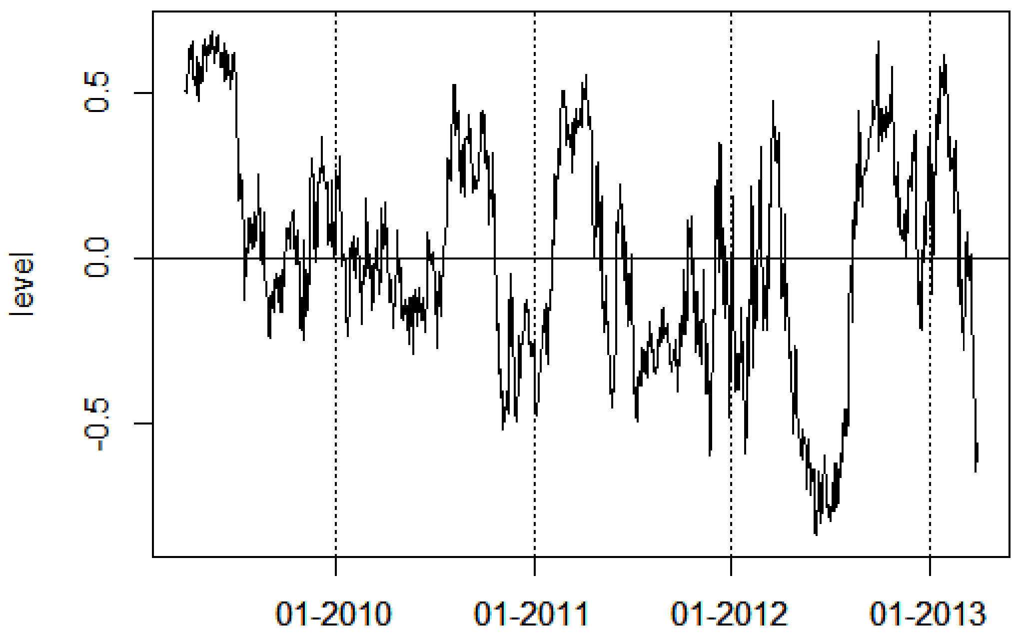
[1] Classification of IMF considers Czech Republic as a developed market but MSCI still considers it as developing. The same applies for South Korea.

[2] The set comprises of MSCI Indexes of following list of countries: Australia, Brazil, Canada, France, Germany, Hong Kong, China, India, Italy, Japan, Malaysia, Mexico, Netherlands, Russian Federation, South Africa, South Korea, Spain, Sweden, Switzerland, United Kingdom and United States of America

Table 4.2: List of countries

Market type	Location	Countries
Emerging Market	CEE	Bulgaria, Czech Republic, Hungary, Poland
	Asia	China, Indonesia, Malaysia, Philippines, Russia, South Korea, Thailand, Turkey
	Latin America	Brasil, Chile, Colombia, Mexico
Developed market	Western Europe	Belgium, Germany, Finland, France, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden
	Other	Australia, Japan, United States

Figure 4.2: GRAI plot from April 2009 to March 2013 (daily)



Source: MSCI, author's computation

of non-overlaping volatility was chosen. This method was inspired also by Uhlenbrock (2009). At the time of data collecting for this thesis, MSCI data were trackable back to beginning of April 2009 at furthest. Corresponding past returns and volatility before this date were proxied by monthly data. The Figure 4.2 plots the outcome. A quick overview of the graph suggests, that during last 4 years the periods of risk appetite were shifting rapidly. In 2012, for instance, rising level of risk appetite was observed in 1st quarter, followed by sudden decline to negative numbers, yet to be followed by rapid growth. This period might elucidate investors' views on equity markets which were rising in 1Q and 3Q and declining in 2Q. The quantitative easing in 3Q could also play a role. Similarly, our graph suggests the period of low risk appetite in second half of 2011. This period is characterized by discussion about second rescue package for Greece in Europe.

4.2.3 Other data

The other data available on daily basis are 10y U.S. Treasury bonds which serve as a global risk-free rate and VIX, the measure of implied volatility on S&P 500 (for further details see Subsection 3.1.2) as an alternative risk appetite indicator. To show that VIX is an alternative risk appetite index, the correlation coefficient between GRAI and first differences of VIX was computed. The outcome was -0.01 (p-value = 0.63) and statistically indifferent from zero. Modelling CDS can also use other series of data. One can for example choose from the pool of various risks like in Fontana & Scheicher (2010). For instance, authors measure leverage risk as the total outstanding debt relative to GDP, liquidity risk as the bid-ask spread on CDS or implied exchange rate volatility of USD/EUR as a proxy to exchange rate. These data are however not analyzed in this thesis due to data availability.

4.3 Results

4.3.1 PCA

The results of Principal Component Analysis are found in Table 4.3. The results indicate that globally, CDS spreads share a big component which accounts for more than 3/4 variation across countries. This component is somewhat stronger for Europe, nearly 84% and very strong for Latin America, nearly 92%. However, the latter may be biased due to small number of countries in the sample. The result for Europe is compatible with research of Fontana & Scheicher (2010) who computed this value to 84.5%. The additional finding of this section is that the common variation is also to be found out of the Europe. For each group, the first component accounts for more than 70% and together with the second factor, it explain over 90% of variation in each separate cluster.

Table 4.3: Principal components

	Global	Europe	Asia	Latin America
Proportionality				
PC1	76.55%	83.81%	72.57%	91.72%
PC2	11.23%	7.74%	19.84%	5.81%

To see, whether risk appetite is somehow related to the principal components, these are regressed on our known indices of risk appetite — GRAI and VIX. The results are displayed in Table 4.4. Comparison between GRAI and

Table 4.4: Regression on the components

Type of indicator	**Group**	**PC1**	**PC2**
GRAI	Global	-0.01 (0.04)	0.20 (0.06)**
	Europe	0.02 (0.03)	0.11 (0.10)
	Asia	0.32 (0.09)***	-0.08 (0.32)
	Latin America	0.30 (0.12)**	-0.18 (0.31)
VIX	Global	-1.16 (0.18)***	-3.01 (0.31)***
	Europe	1.67 (0.18)***	-2.92 (0.50)***
	Asia	-1.54 (0.49)**	-2.52 (1.70)
	Latin America	-8.06 (0.57)***	-1.52 (1.52)

*** – significance on 0.1% level, ** – significance on 1% level, * – significance on 5% level. Slope coefficients are multiplicated by 100. Intercept was omitted due to large insignificance in all cases.

VIX suggests that VIX is generally more successful in predicting common moves in CDS. Particularly, the VIX may incorporate information for each first component and for two second components out of four. On the other hand, GRAI wins over VIX only in case of first component of Asian countries. The second component of global moves can be to some extent also explained by GRAI, but for this component the VIX has already stronger predictive role.

4.3.2 Econometric analysis

The econometric analysis was counducted as previously stated. The outcomes are divided in two groups: developed markets and emerging markets. The results for the group of developed markets are described in Table 4.5. In the group of 14 countries, only two countries satisfy the significance of risk appetite - Australia on 0.02% level of significance and, surprisingly, Norway on 2.71%

level of significance. U.S. Treasury bonds have been found significant only for 5 countries.

Table 4.5: Regression — developed markets

country	GRAI_coeff	GRAI_p-val in %	Tbond_coeff	Tbond_p-val in %
AUS	-3.78	0.02***	1.71	8.71
GER	-1.05	29.48	-2.36	1.84*
FIN	-1.36	17.51	-0.17	86.69
FRA	-0.56	57.79	-2.20	2.80*
IRE	-0.08	93.77	-0.99	32.40
ITA	-0.81	42.06	-3.12	0.19**
JAP	-1.30	19.52	-1.54	12.28
NL	-1.43	15.44	-1.93	5.43
NOR	-2.21	2.71*	0.03	97.91
POR	-0.17	86.83	-1.55	12.25
SPA	-0.38	70.75	-2.54	1.13*
SWE	-1.40	16.16	-0.65	51.54
UK	-0.85	39.35	-1.65	9.97
USA	-1.08	27.92	-2.88	0.41**

*** – significance on 0.1% level, ** – significance on 1% level, * – significance on 5% level. Slope coefficients are multiplicated by 100. Intercept was omitted due to large insignificance in all cases.

The results for the group of emerging markets are described in Table 4.6. The results here are more optimistic than in the table above. Risk appetite has been found significant on favourable levels of significance for 10 countries out of 16 countries in this sample. The interesting result of this part is that risk appetite have been found extremely important for the Asian countries (Indonesia on 0.1% level; China, Malaysia, South Korea and Thailand on 1% level and Philippines on 5% level). Strong predictive power of U.S. Treasury was found for Brazil, China and Mexico. Yet, three CEE countries (Bulgaria, Hungary and Poland) indicate some relationship with Treasury bonds but not with GRAI. On the other hand, the remaining country, Czech Republic, was found to be explained by GRAI rather than Treasury bonds.

Table 4.6: Regression — emerging markets

country	GRAI_coeff	GRAI_p-val in %	Tbond_coeff	Tbond_p-val in %
BRA	-2.04	4.20*	-3.58	0.04***
BUL	-2.06	3.93*	-2.74	0.63**
COL	-2.39	1.69*	-3.19	0.15**
CZE	-2.07	3.83*	-1.83	6.70
HUN	-1.62	10.58	-2.24	2.56*
CHI	-1.45	14.67	-4.77	0.00***
CHN	-3.04	0.25**	0.94	34.63
INA	-3.56	0.04***	-0.64	52.28
KOR	-2.95	0.32**	0.33	74.52
MAL	-3.18	0.15**	0.52	60.46
MEX	-2.09	3.67	-4.56	0.00***
PHI	-2.45	1.43*	-0.76	44.55
POL	-1.54	12.33	-2.12	3.39*
RUS	-1.70	9.01	-1.64	10.17
THA	-2.96	0.32**	0.21	83.36
TUR	-1.15	25.22	-1.81	7.05

*** – significance on 0.1% level, ** – significance on 1% level, * – significance on 5% level. Slope coefficients are multiplicated by 100. Intercept was omitted due to large insignificance in all cases.

4.3.3 Granger causality

The results of Granger causality test are described in Table 4.7.[3] Our hypothesis presumes GRAI to Granger cause countries' CDS spreads. However, this expectation is false as one can confirm in the last column of the table. Out of 31 countries in our sample, only Australia is proven to be Granger caused by GRAI and in the same time, the role is stronger than in the case of opposite direction. On the other hand, the results suprisingly confirm reverse causality. The first lag of risk appetite has strong predictive power on basis of 1% level for 24 countries out of 31.[4] The second lag p-value is computed under F statistic. This methodology is false according to Hamilton (1994) who proposes alternative statistic under χ^2 distribution. Under this method, only the countries for which F-statistic was computed above 6 can be found significant. Thus, we obtain only 20 countries out of 24 from the first lag.

[3] The countries acronyms marked in bold are the countries for which econometric analysis in previous section found significant role of risk appetite.

[4] In addition, Australia resulted significant on 3% level and Norway marginally unsignificant on 5% level.

Table 4.7: Granger causality

	CDS G-causes GRAI				Grai G-causes CDS
country	level of significance in		F statistic		level of significance
	(lag 1) in %	(lag 2) in %	(lag 1)	(lag 2)	(lag 1) in %
AUS	3.00	4.67	4.72	3.07	1.39
BEL	0.00	0.00	18.80	10.08	47.07
BRA	0.00	0.00	18.34	10.65	30.50
BUL	0.02	0.05	14.09	7.71	55.04
COL	0.03	0.03	13.30	8.26	15.11
CZE	0.01	0.01	16.19	9.04	52.84
GER	0.95	4.31	6.74	3.15	52.83
FIN	0.45	0.57	8.09	5.19	69.57
FRA	0.05	0.11	12.16	6.81	56.22
HUN	0.44	1.37	8.14	4.31	35.04
CHI	0.43	0.47	8.17	5.39	20.28
CHN	0.03	0.04	13.01	7.93	21.91
INA	0.04	0.05	12.74	7.76	15.12
IRE	0.08	0.23	11.25	6.10	39.09
ITA	0.00	0.00	29.20	14.41	80.25
JAP	17.93	25.23	1.81	1.38	43.98
KOR	0.16	0.18	9.97	6.35	27.29
MAL	0.15	0.13	10.15	6.72	13.36
MEX	0.00	0.00	17.75	10.68	49.16
NED	0.00	0.01	18.47	9.74	90.95
NOR	5.10	0.45	3.82	5.43	21.49
PHI	0.01	0.01	15.61	9.22	56.46
POL	0.00	0.00	24.36	12.71	75.40
POR	0.31	0.81	8.81	4.83	53.91
RUS	0.00	0.00	18.58	10.81	92.78
SPA	0.00	0.00	20.86	10.22	67.05
SWE	75.43	0.78	0.10	4.87	26.28
THA	0.07	0.11	11.60	6.88	26.80
TUR	0.00	0.00	29.33	14.90	80.75
UK	17.25	18.26	1.86	1.70	60.45
USA	22.92	41.28	1.45	0.89	51.55

Out of the original set of 5 hypotheses, hypotheses number 1 to 4 are accepted. A significant principal component was found. Also, an association with the first two components was found for VIX in each group and for GRAI in case of Asia and Latin America. Risk appetite playing role for emerging markets was found too, whereas developed markets are probably subject to different measures. Hypothesis number 5 is rejected – the Granger causality from GRAI to CDS was not found.

Chapter 5

Conclusion

The thesis has studied and summarized contemporary knowledge of risk appetite. Risk appetite is a relevant factor which comes to asset prices daily. Because of its importance, several methods have been proposed to gauge this phenomenon. Besides practitioners indices, various measures based on economic theory exist in which one can choose from two wide families of theory-based risk appetite indices. These are GRAI indicators and option-implied indicators, but there are of course other more sophisticated methods which were omitted due to the scope of this thesis. Finally, the notion of risk aversion and appetite can also be extended by findings of behavioral economics.

The practical part analyzes sovereign risk determination by risk appetite for 31 countries divided in 4 groups (World, Europe, Asia and Latin America). The large principal component in each of the four groups was found suggesting strong comovement both in groups and across globe. The econometric regression suggests that the risk appetite measured by VIX may lie behind the movement. Results for GRAI are middling in this analysis. There have also been found that risk appetite plays more important role for emerging markets, rather than for developed markets. Granger causality, however, does not prove that risk appetite could Granger cause CDS. In fact, this direction is opposite.

So far, there is still very much to do in research on this topic. One can, possibly, apply similar models with extended number of variables to see whether risk appetite perceives. An alternative dataset for GRAI computation or application of orthogonalization of Misina (2006) or normalization-plus of Uhlenbrock (2009) on the computation is also a possibility. On the other hand, behavioral economists also offer many methods how to gauge for investors' sentiment. The choice is on subsequent research.

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