Frankfurt School – Working Paper Series

No. 81

Commodities in Asset Management

by Nadeshda Demidova-Menzel, Thomas Heidorn

August 2007

Frankfurt School of Finance & Management
Bankakademie | HfB

Sonnemannstr. 9 – 11 60314 Frankfurt an Main, Germany
Phone: +49 (0) 69 154 008 0 Fax: +49 (0) 69 154 008 728
Internet: *www.frankfurt-school.de*

Abstract

The investment in commodities is starting to be more important during the last years. The paper describes the characteristics of financially important commodities. In many cases a passive investment in an index is most suitable. As the GSCI is found to be the most important, its underlying futures are analyzed. The change of risk-return relationships in equity and bond portfolios including commodities is discussed. The paper shows that the effects differ substantially during different holding periods. Especially during times of high inflation and strong equity markets, commodities were a sensible addition. Still, the total performance from 1976 to 2006 was not convincing. This paper reveals that the performance does not mainly depend on the spot return but more on roll and collateral return.

Key words: commodities, investable commodities, commodity future, commodity index, GSCI, portfolio optimization with commodities, spot return, roll return, collateral return

JEL classification: G11, G15, G24.

ISSN: 14369753

Contact:

Nadeshda Demidova-Menzel
equinet AG (ESN)
Gräfstr. 97
D 60487 Frankfurt am Main
Nadeshda.Demidova@equinet-ag.de

Prof. Dr. Thomas Heidorn
Frankfurt School of Finance & Management / HfB
Sonnemannstr. 9 – 11
D 60314 Frankfurt am Main
t.heidorn@frankfurt-school.de

.

Content

1 Introduction

Historically, commodities played a minor role in the investment decisions of institutional asset managers and private investors. According to an estimation by Goldman Sachs, the fund managers weighted commodities with only 2 to 4 percent in their portfolios in 2005.

However, in the last few years a growing interest of investors in commodities has been observed. In a Barclays survey (2005), conducted with 150 fund managers, 66 percent of them said that they are aiming to increase the commodity weight to 6 and more percent in the next three years. The US mutual funds increased their investments in commodity indices from USD 300m in 2002 to USD 7bn in 2005.[1] Worldwide current net value of commodity-indices-based investments of institutional asset managers is estimated at USD 87.9bn. USD 10.8bn are bound in the Dutch pension plan funds ABP, PGGM, and PME that discovered commodities as an investment alternative some years ago.[2]

The advantages of commodities as an asset class are obvious and empirically evident. Over time commodities have demonstrated a low, and in some cases negative, historic correlation of returns with stocks and bonds as well as a positive correlation with the consumer price increase (inflation rate). These characteristics imply that including commodities in a traditional stock and bond portfolio can reduce the overall portfolio risk and improve the risk-adjusted performance characteristics of the total portfolio. Additionally, it is a fact that over the past 45 years, a diversified commodity futures portfolio has returned the same risk premium as the Standard & Poor's 500.[3] However, the sources of these returns should be analysed carefully.

The main reasons for the investors' interest are the globalisation and a rising demand of the producers and consumers for commodities in Emerging Markets like China, India as well as an underinvestment in commodities production in the past 10 to 15 years which has resulted in an insufficient supply and a rocketing price development. Another reason is the investors' disappointment with the performance of the stock market after the "technology-bubble"-era.

The objective of this work is

- to describe investment opportunities in the commodity market,
- to explain how the return-risk-ratio can be improved with the involvement of commodities in a passive investment strategy based on portfolio selection models,
- to examine whether commodities are always a reasonable component in a portfolio or if there are phases unsuitable for investments in commodities.

[1] Cf. Atonce Capital Management, online: without page
[2] Cf. Mezger, M./Eibl, C. (2006): p. 20
[3] Cf. Brown, S.P. (2006): p. 44

2 Investments in Commodities

2.1 Commodity Definition

In the narrowest sense and according to the economical categorisation used in national accounting, non-financial commodities are defined as "essential raw materials" that come from the primary sector, which includes agriculture and mining. In the widest sense, the term "commodities" also contains semi-finished products used by producers and consumers, although a significant proportion of the value of such products has been added by the manufacturing sector through the activities of slaughterhouses, pulp mills and copper smelters, refineries, etc. (e. g. meat, paper pulp and refined copper).[4] Electricity as well as modern commodities like bandwidth, and so called negative commodities such as emissions credits or weather events, are not the subject of this work.

The financial view of commodities in this paper signifies that an investor looks at all transportable natural resources, raw materials and products which are traded with competitive bids and offers. The major favourable aspects are cash settlement only and low transaction cost. Generally, the focus lies therefore on commodity future and investable indices. The special points of interest are the following five sub-categories:

(a) Energy which includes crude oil, heating oil and natural gas,

(b) Precious Metals comprised of gold, platinum and silver,

(c) Industrial, or so called Base Metals, which consist of aluminium, copper, lead, nickel, zinc, tin,

(d) Agricultural Products which include corn, soybeans and wheat (Grains) as well as cocoa, coffee, cotton, orange juice and sugar (Soft Commodities),

(e) Livestock including live cattle and live hogs.

In the following sections the characteristics of single commodity groups are presented.

2.2 Energy

There are two well-known types of crude oil (petroleum) which are used as pricing benchmark for other types of oil on the commodity exchange: **West Texas Intermediate (WTI)** and **North Sea Brent Crude**.[5] Other types of oil are traded with discount on the price of the

[4] Cf. Radetzki, M. (1990): p. 2.
[5] Dubai Fateh is the crude oil type traded in Asia

reference oil type. Both types are characterized as *light sweet crude oil.*[6] This name is given to barrels of crude oil that meet certain content requirements, such as low levels of sulphur (for sweetness) and hydrogen (for lightness, or rather gravity). This type of oil is much easier to refine into gasoline (petrol), diesel, fuel oil/heating oil than sour crude. Most of US refineries (in the Midwest and on Gulf Coast) are able to refine only light sweet types of oil. Sour types of oil need more refining to meet current end-product specifications and the refining process of sour types of oil is much more difficult and expensive. Typically, the North Sea Brent Crude is refined in Northwest Europe, but when the market prices are favourable for export, it can also be refined in the East or on the Gulf Coast of the United States or in the Mediterranean.

The price per barrel of oil is therefore highly dependent on both its gravity grade (API) and its sulphur content.

Sweet crude future contracts are the most popular oil contracts traded on the commodity markets. WTI is the underlying commodity for the future contracts traded on the New York Mercantile Exchange (NYMEX), whereas Brent Crude is the underlying one for the commodity future exchange International Petroleum Exchange (IPE) in London. Moreover, Brent Crude is the pricing benchmark for the oil production from Europe, Africa and the Middle East (for more than 65% oil stocks traded worldwide).

Because of the higher quality and properties of WTI, the typical price difference per barrel between WTI und Brent Crude is about 1 USD, the price difference between WTI and **OPEC Basket**[7] is about 2 USD.

Natural gas is traded in 10,000 million British Thermal Units (MmBtu)[8] and is the underlying of future contracts traded on the NYMEX.

Heating oil is the second most important fuel after natural gas in the United States. It is a flammable liquid petroleum product with a low viscosity, used to fuel building furnaces.

Heating oil accounts for about 25% of the yield of a barrel of crude oil, the second largest end-product share after gasoline (petrol). The heating oil futures contract are traded in units of 42,000 US gallons (1,000 barrels) and based on delivery in the New York Harbor. Options on futures, calendar spread options contracts, crack spread options contracts, and average price options contracts give market participants even greater flexibility in managing price risk.

[6] WTI-oil is lighter (API-gravity~39.6) and sweeter (0.24% sulphur) than Brent Crude (API-Gravity ~38.6; 0.37% sulphur); **API-Grade/API-Gravity** (American Petroleum Institute-Grade) or **viscosity** is a conventional, common gravity unit for crude oil. It is used as a characteristics and quality benchmark for crude oil worldwide. Crude oil with API-Grade higher than 31,1 °API is classified as „light“, in the range of 22,3 °API und 31,1 °API as "middle" and below 22,3 ° as "heavy".

[7] OPEC Basket = average price of 11 types of oil from the OPEC-countries. The OPEC-oil is heavier than both Brent and WTI, and contains more sulphur. It is mainly refined in Asia.

[8] mmBtu is equal 1.058 GJoule

The heating oil futures contract is also used to hedge diesel fuel and jet fuel, both of which trade in the cash market at an often stable premium to NYMEX Division New York Harbor heating oil futures.

2.3 Precious Metals

The group of precious metals includes gold, silver as well as metals of the so called PGM-Group[9] including Palladium and Platinum. A specialty of precious metals compared with many other commodities is their feasibility of storage at tenable costs.

Gold, silver and platinum future contracts are traded on the Commodity Exchange (COMEX) of the NYMEX and on the Chicago Board of Trade (CBOT); palladium future contracts only on the COMEX.

On the one side, **gold** is a "real" commodity used for consumption and production. On the other side, gold is considered to be a financial monetary asset. About 15% of the annual gold production is held by investors in physical form[10] and provides a natural hedge against currency weakness because of a verified statistically significant negative correlation to the USD.[11] Since a few years there is a supply deficit for gold which is primarily satisfied through the sale of central banks' holdings. It is estimated that there is a direct relationship between the COMEX warehouse stocks and gold price movements suggesting that the COMEX warehouse stocks may be a useful proxy for the short-term supply-demand balances.

Silver is the second most important precious metal. Silver is a by-product from the mining of the base metals copper, lead and zinc. In the USA the mining of industrial metals makes up 50% of silver production. Therefore, silver supply is strongly correlated with the supply of base metals. Nearly 21% of silver production resulted from recycling in 2004. The demand for silver has exceeded the supply for many years what results in the worldwide silver stocks' decline. Unlike gold, there is little relationship between silver inventories on the COMEX and the silver price.[12]

The **platinum** market was characterised by a supply deficit in the last years. The platinum demand is expected to increase further in the next several years because of the new auto-emissions-regulation Euro V (2008) and Euro VI (2010/2011) as platinum is used in the automotive sector for production of catalytic converters on a large scale. The second field of usage is the jewellery sector. Increasing production volume of fuel cells will also cause further demand, with an estimated increase of 10% till 2015. Because of similar chemical char-

[9] **PGM = Platinum Group Metals** include besides platinum and palladium also rhodium, iridium, osmium, and ruthenium

[10] According to the statistics of the World Gold Council, the World Official Gold Holdings of Central banks amount to 30,988.3 tons as of December 2005; approximately 26% is held by the Federal Reserve Bank

[11] Cf. Kavalis, N. (2006): pp. 3ff.

[12] Cf. GFMS (2005): pp. 5ff.

acteristics, platinum can be substituted with cheaper palladium in all fields with the exception of the jewellery sector, in case of platinum shortage and resulting high prices.

2.4 Industrial Metals

The group of industrial metals includes aluminium, lead, copper, nickel, zinc and tin. They are traded on the London Metal Exchange (LME), and some of them also on the COMEX. The demand for base metals is considered to be dependent on the worldwide economical development. The growing demand for industrial metals in the emerging markets is the reason for a possible shortage, and therefore an increase in prices.[13]

All industrial metals run through a two-steps process consisting of mining and processing.

A quarter of **aluminium** production costs are energy costs, that is why the aluminium price is positively correlated with the oil price. Over 60% of annual aluminium production comes from recycling. This percentage is expected to increase over time. It costs far less to produce aluminium as well as other metals from scrap than to extract it from bauxite ore. Aluminium is used in the automotive industry (26% of the total demand), packaging industry (22%) and construction industry (22%). The supply excess in 2001-2003 changed to a supply deficit in 2004-2005.

The worldwide resources of **copper** are estimated at 2.3 billion tonnes: 1.6 billion tonnes on the mainland, and 700 million tonnes on the seabed. It is widely believed that copper demand is closely linked to the economic cycle or, put more strongly, that global economic growth is the principal factor that drives demand for copper. Therefore, demand for copper (but not the copper price!) is strongly pro-cyclical.[14] More than 40% of demand derives from the construction industry, with electrical and electronic products accounting for an additional 27%. Since 2003 the demand for copper exceeded the supply so that copper inventories on the LME and COMEX are almost completely exhausted. The LME copper stocks changes provide investors with a useful, timely price indicator. The BMO Financial Group's Commodity Price Report from July 19, 2006, reports: "With [copper] inventories at critically low levels, demand firming amid healthy global economic growth, and production gains likely limited, the resulting tight market balance should keep prices high, even if volatile, during the rest of the year." BMO Financial Group pointed out on May 9, 2006: "With supplies already stretched and demand strong, prices received further impetus from a drop in LME inventories, supply disruptions in Chile and Mexico, and buying by investment funds [...] Inventories are currently at critically low levels, demand is strengthening amid strong global economic growth as well as for seasonal reasons, and production gains are limited. Together, these factors suggest continued high prices in the short term."

Lead and zinc are the two most widely used non-ferrous metals after aluminium and copper. **Lead** can be found in ore together with copper, zinc and silver. The mining of lead is mostly

[13] Cf. Pulvermacher, K. (2005b): pp.2 ff.
[14] Cf. Pulvermacher, K. (2005b): p. 5

carried out in the developing countries while the smelting mainly takes place, with exception of China, in western industrial countries. More than 50% of lead supply comes from recycling, and this secondary supply from recycled scrap plays an increasing role. Therefore, mine production alone is not a particularly useful proxy for supply, and is expected to become less useful over time. The biggest use of lead is in lead acid batteries, which accounts for a steadily growing share of demand to 78% in 2004. These batteries are used in vehicles, and also in emergency power systems, for instance in hospitals. This share has remained remarkably constant over time. Currently lead is often substituted by synthetic materials, plastic, aluminium, iron and tin. Similar to copper, movements in LME inventories inform investors about possible future changes in the lead price.

Worldwide reserves of **zinc** are estimated at 1.9 billion tonnes, the annual zinc production amounts to approximately 10 million tonnes. The zinc processing has a very high price elasticity because the mining companies have shown that it is possible to increase production in case of increasing prices. The existing “bottleneck factor” is the limited capacity of the smelting plants. The use of zinc as a protective coating for other metals, such as iron and steel, in a process known as galvanization, accounts for more than half of the zinc consumption. Zinc is also used as an alloy with copper to make brass. 45% of the annual zinc production is used in construction, 25% in the transport sector, a further 23% in the consumer and electrical goods sector. Unlike copper and lead, the relationship between LME zinc stocks and price movements is not very clear-cut.

As with aluminium, copper and lead, the value of the annual **nickel** demand has increased dramatically in the last years resulting in an enormous price jump. The most important field of usage of nickel is the manufacturing of stainless steel (66%). High nickel prices caused the new demand trend for steel with a low proportion of nickel.

2.5 Agriculture

Various primary agricultural products belong to the group Agriculture which is subdivided into Grains and Soft Commodities (or short: Softs). Cacao, cotton, coffee, orange (juice), sugar belong to the group of Soft Commodities while corn, soybeans as well as wheat are included in the Grains group.

The most important exchanges for agricultural products are the Chicago Board of Trade (CBOT), the Kansas City Board of Trade (KCBT) and the New York Board of Trade (NYBOT).

In times of increasing energy prices, alternative fuels starts to play an important role. Agricultural products like corn, soybeans, sugar, and wheat are considered to be suitable constituents for the production of bio fuel. Wheat is expected to become the main feedstock for ethanol making in Europe, corn in the USA and sugar cane in Brazil. Such new evolutions of the usage of agricultural products have an effect on their price development and on the correlative relationship to the energy markets. Ron Plain, an agricultural economist at the University of

Missouri, said: "The whole agricultural industry is starting to become aware of what ethanol plant construction means to the future. It gives us an outlook of even higher corn prices for as far as we can see".

2.6 Livestock

The category Livestock is comprised of live cattle, feeder cattle, and lean hogs. The livestock futures are traded on the Chicago Mercantile Exchange (CME). The CME offers a range of futures and options on livestock, e.g. CME Feeder Cattle Futures and Options (young cattle), CME Live Cattle Futures and Options (market ready animals), CME Lean Hog Futures and Options, CME Frozen Pork Belly Futures and Options (the first futures on frozen meat products, launched in 1961). The CME Feeder Cattle and CME Lean Hog contracts are settled in cash and not physically deliverable, while the CME Live Cattle and CME Pork Bellies are physically deliverable.

The US livestock industry is currently estimated at USD 60bn annually for cattle and hogs, and is very risky. Extremes in weather can greatly affect the cost of feed, rates at which animals gain weight, and how many animals survive to bring to market. Prices vary depending on the amount of inventory in cold storage and the seasonal demand. Even during periods of record-breaking prices, all sorts of other events can take place to increase or decrease supply and demand for livestock. For example, livestock diseases such as BSE affect the livestock prices as they have direct consequences on export perspectives. Also, shifting public tastes for consuming beef and pork is a driving factor of the livestock prices.[15]

2.7 Other Commodities

This group includes unique opportunities with direct links to natural resources which exist outside global commodity exchanges only, with a limited access for investors because they are usually not available via futures markets. The examples are water and timberland.

Water is the world’s most precious commodity and can not be substituted by any other natural resource. The complexities related to the sourcing and distribution of water offer a myriad of business and investment opportunities. However, there is no water futures contract to consider. Few existing mutual funds represent a way to access a direct investment in companies in the water sector.

In the last years mainstream investors such as pension funds, insurance companies and university endowments spotted **timberland** as an interesting asset class with high returns and low risk. For example, Harvard University allocates 10% of its nearly USD 26bn endowment to timber. Although Harvard recently sold most of its US forest holdings to another financial

[15] Cf. CME (2005): p. 10

investor, the university is looking for new land to buy. Yale also invests in forests, as various pension funds, insurance companies and charitable trusts also do.

Unlike other hard asset classes, timberland is unique because the owner of the timber has the option to defer cutting the timber. For individual investors, direct investing in timberland is difficult. There are a number of timber-only companies publicly traded, but that is different from the direct ownership share in those companies. The public equity will be more volatile than the private partnerships.

Lumber is a more easily investable wood product. [16] Lumber futures are traded on the CME, and are constituent of Rogers International Commodity Index with weighting of 1%. With the launch of the lumber future contracts in 1969, CME became the first exchange to offer price protection to the forest products industry. Companies engaged in producing, processing, marketing or using lumber and lumber products have been able to hedge their risk exposure and reduce the risk of holding or acquiring inventory through taking an equal and opposite position in CME lumber futures. Individual investors can trade lumber, too.

Lumber, or timber, like any other commodity, experiences price fluctuation according to the laws of supply and demand. Lumber prices are however unpredictable and volatile. Supply can be constrained due to mill closings, environmental policies and other factors. Demand also tends to shift rapidly, based on interest rates and other economic conditions that affect housing starts. As a result, lumber prices react to supply and demand imbalances with frequent and often extreme changes.

Highly volatile prices can mean an opportunity for large profits. But in an industry like the lumber industry, valued at USD 30bn for the North American market alone, where costs are high and margins are tight, volatile prices can also mean the risk of loss.

The lumber price is positively correlated with mortgage rates and housing demand. Lumber prices have been falling for most of 2006 with rising mortgage rates and lower housing demand. In the big picture, the forest industry has not been overly profitable and many traditional lumber companies have been selling their timber land and are moving towards consumer products what will cause a supply shortage in the medium-term.

3 Commodities as an Asset Class

The growing use of commodities in institutional portfolios has raised the question whether commodities should be considered as a separate asset class.

An **asset class** is a specific category of assets or investments, such as stocks, bonds, international securities, real estate, etc. Assets within the same class generally exhibit similar characteristics, behave similarly in the marketplace, and are subject to the same laws and regula-

[16] **Lumber** is wood that has been cut and surfaced for construction use. **Timber** is a size classification of lumber that includes pieces that are at least five inches in their smallest dimension.

tions. This traditional definition of an asset class is based on the inherent attributes of the assets. For example, an asset class should be composed of investment opportunities that have a common, identifiable underlying economic driver, have a common legal and regulatory structure, correlate highly with one another, have fairly stable risk and return characteristics, and can be captured by investable benchmarks.[17]

An asset class as a whole minimises the return as well as the volatility estimation error of individual investments by aggregating them and exploiting the resulting error diversification effect. The result is a representation of the asset class as a part of the investment opportunity set[18] with stable return, risk, and correlation characteristics that can be used in asset allocation modelling.

Therefore, commodities should satisfy a number of criteria in order to be accepted as an asset class. The criteria used to define an asset class are the following:[19]

1. Homogeneity within the class: securities (like commodity futures) included in the class should be more conceptually similar to each other than to securities excluded from the class. High correlation with other assets within the class: returns of securities included in the class should be more highly correlated with each other than with returns of securities outside the class.

2. Sufficient Market Capitalisation: the asset class in aggregate should represent an important fraction of the investment opportunity set.

3. Availability of pricing and composition data.

4. Investability: it should be possible to invest in the asset class passively, at quoted prices.

Considering and evaluating commodities against each of these criteria, the results are the following:

1. Commodities, or at least commodity groups, are homogeneous. All tradable commodities are subjected to the standardisation convention to be flexibly tradable.

2. Although commodity groups show a relatively low correlation between each other (cf. Section 5.4), they show an even lower or rather negative correlation to other asset classes such as stocks and bonds commodities.

3. Approximately USD 88bn are invested in the commodity market. This satisfies the criterion of materiality and importance.

[17] Cf. Singer, B. D./Staub, R., Terhaar, K. (2002): pp. 4ff.
[18] An investment opportunity set includes e.g. stocks, bonds, private equity, hedge funds, commodities, etc.
[19] Cf. Oberhofer (2001): p. 1f.

4. Data concerning commodities prices, index compositions, price driving factors is available and sufficient.

5. It is possible to invest passively in futures on several existing commodity indices.

Therefore, commodities can be treated as an asset class and involved in the asset allocation process.

3.1 Benefits of Commodity Investments

On the one hand, the low correlation to other asset classes nominates commodities as a portfolio **diversifier**. Commodity investments are generally considered to be risky for most investors because of their extremely high volatility. But for fully collateralised well-diversified commodity-futures-based index investments this high risk characteristic does not apply, and thus such investments can be a potential investment interest for e.g. pension funds.[20]

On the other hand, another important characteristic is that commodities are **real assets**, whose prices might be strongly influenced by the inflation rate. In opposite to **nominal assets** like stocks or bonds, real assets are fixed in supply and generate no income stream, but their exchange value is more stable because their price changes if the money price changes.[21] While the interest paid on a bond compensates investors for the expected rate of inflation, the unanticipated inflation damages the exchange value of nominal assets. But real assets like commodities might offer a **natural hedge** against such **unexpected, unanticipated inflation**.[22]

In 1997, Kaplan and Lummer updated the previous study of Lummer and Siegel from 1993 which provided an empirical evidence that a collateralised position in GSCI futures is both a good diversifier for stocks and bonds, and an effective hedge against inflation. Kaplan and Lummer found out that a reversal in the signs of five-year monthly correlations between the returns on GSCI collateralised futures and the returns on stocks, bonds, and inflation took place. They concluded that while GSCI collateralised futures provide diversification for stocks and bonds in the long run and also serve as a hedge against inflation, they do not always do so over short periods of time.[23] In 2006, Erb and Harvey argued that this might not be contributed to the excess return but rather be linked to other factors in a total return environment.[24]

[20] Cf. Ankrim, E./Hensel, C. (1993): p. 22

[21] Cf. Greer, R. J. (2005): p. 24

[22] Cf. Ankrim, E./Hensel, C. (1993): (1993): p. 20; Kavalis, N. (2006): pp. 3ff.; Greer, R.J. (1994): p. 28; Cf. Gorton, G./ Rouwenhoorst , K.G. (2004): pp. 18f. As a general rule, commodities are priced in US dollar, therefore all studies analyse the relationship between the US dollar and commodity prices.

[23] Cf. Lummer, S.L./Siegel, L.B. (1993): pp. 75ff.; Kaplan, P.D./ Lummer, S.L. (1997): pp. 11ff.; Cf. Gorton, G./Rouwenhoorst , K.G. (2004): p. 15

[24] Cf. Erb C. B. / Campbell R. H. (2006) pp. 76ff.

3.2 Commodity-Related Investments

Although the term "commodities" includes an extraordinarily wide range of goods, the universe of investable commodities is restricted to a small sub-set of commodities. The range of investment methods and investment products available for a given commodity reflects the nature of the commodity itself as well as established patterns of supply and demand. The type of access to different commodities is also determined by market size for each single commodity.[25]

Such an access for investors can be divided into three types: direct ownership of the commodity itself, investment in producing companies, and investments in commodity futures, options, other derivatives and structured products.

3.2.1 Direct Investments in Physical Commodities

Very few commodities lend themselves to direct ownership or investment directly in the commodity itself, as the possibility of doing this depends on the **feasibility of the commodity storing**. This is generally applicable to the precious metals but it does not mean the investor is required to receive a physical delivery of the metal. A range of sophisticated alternatives exists: metal accounts, exchange traded funds, collective investment vehicles and so on. However, transaction costs are excessively high.[26] For some commodities like coal, uranium, etc. there is no possibility to invest in them physically.

3.2.2 Direct Investments in Commodity-Related Companies

Investing directly in companies in the area of exploration and production of commodities (e.g. equity or debt ownership) provides an alternative method to access price movements in the underlying product, although this is not a "pure play" for the following reasons:[27]

- many companies in the natural resources sector are diversified, so the investor is unlikely to get exposure to a specific single commodity,
- the performance of a single company is directly linked to the market price of commodities, but also to many other factors which influence earnings of that company such as interest rates, wage rates and exploration costs,
- corporate activity may impact share prices more than the value of the underlying asset (in this case commodity).

Thus, it is questionable in how far the investor participates on the development of commodity prices because the financial success of every single company is influenced by a number of

[25] Cf. Pulvermacher, K. (2005a): pp. 6f.
[26] Cf. Pulvermacher, K. (2005a): p. 6
[27] Cf. Gorton, G./Rouwenhoorst , K.G. (2004): pp. 26f.; Pulvermacher, K. (2005a): p. 6

other varying factors. Consequently, earnings are more related to the state of the economy and the management decisions than the commodity price.

An evidence that such indirect commodity investment, through debt and equity instruments in commodity-linked firms, does not provide direct exposure to commodity price changes, was provided by Schneeweis and Spurgin (1997) with the example of energy companies.[28]

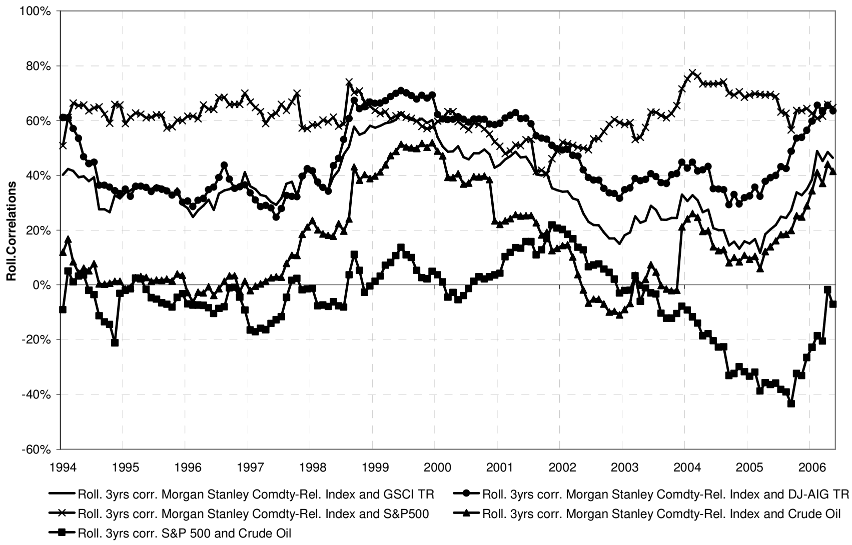
It is also well known that many commodity-based firms hedge their exposure to commodity price fluctuations. To the degree that firms hedge a major portion of the commodity risk, even commodity-based firms may not be exposed to the risk of commodity price movement. As a result, investment in commodity-linked equities does not replicate the unique price-return behaviour of direct commodity investment. In a paper of the Center for International Securities and Derivatives Markets (CISDM), the relationship between the return properties of commodity-linked equities (Standard & Poor's Energy, Industrial Metals, and Agriculture indices) and the corresponding Goldman Sachs Commodity Index and Dow Jones-AIG Commodity Index was analysed. The result of the study was the insight that direct investment in commodities often provided a positive return when commodity-linked stocks lost money.[29]

Exhibit 1 shows the strength of the relationship between monthly changes in the share prices of commodity-related companies (represented by Morgan Stanley index) and the actual commodities prices. It is clear that the relationship between commodity-related companies and the overall equity market (represented by Standard & Poor's 500 index) is far stronger than the relationship between commodity-related companies and actual commodity prices. Also shown is the correlation between oil prices and the broader US market as well as commodity-related companies.

The correlation between commodity-related companies and the rest of the equity market is consistently higher than with the underlying commodities themselves. Consequently, having exposure to commodity companies is not the same as having direct commodity investments. Commodity-related stocks are a weak substitute for their underlying commodity.

[28] Cf. Schneeweis, T./ Spurgin, R. (1997): pp. 3ff.
[29] Cf. CISDM (2005): pp. 17f.

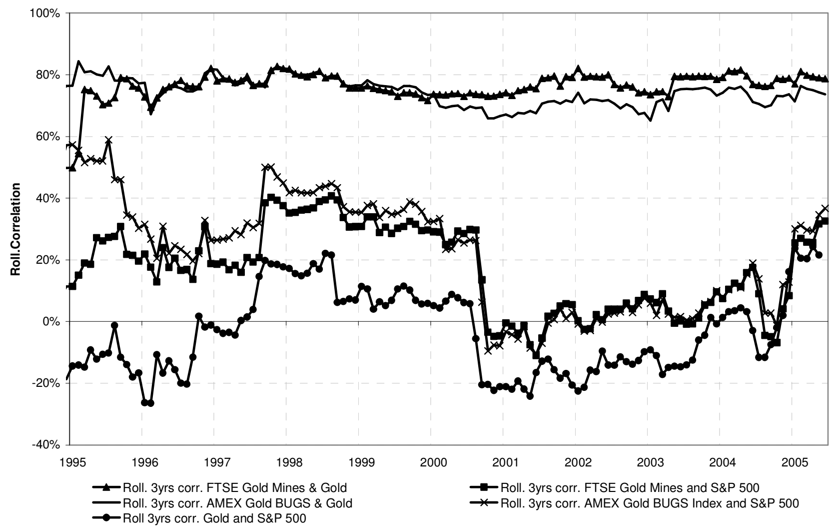
Exhibit 1: Rolling Correlations of the Commodity and Commodity-Related Equity Indices (1994-1.H.2006, monthly changes)



Source: Bloomberg (data)

The chart below (Exhibit 2) shows an opposite picture for the special case of precious metals exhibiting the correlation between monthly changes in the share prices of gold mining companies and actual gold spot prices. Also, the correlation between share prices of the gold sector and the broader US equity market is shown. It is clear that the relationship between gold mining companies and the actual gold prices with approximately 80% is far stronger than the relationship between gold mining companies and the overall equity market.

Exhibit 2: Rolling Correlations of the Gold Mines Indices, S&P 500 and Gold Spot Price (1995-1.H.2006, monthly changes)



Source: Bloomberg (data)

Consequently, having exposure in gold mining companies is nearly the same as having gold investments.

3.2.3 Investment in commodity futures

Commodity futures are exchange-traded standardized contracts that oblige the buyer, to buy a definite quantity of a specific commodity at a future delivery date to a price fixed in advance. The future buyer assumes that the price of the commodity increases at due date. The contracts are usually settled in cash, without delivery of physical commodity. All over the world, there are more than 70 exchanges where commodity futures are traded, although many of these are limited in terms of the volume of trades and the range of commodities covered.

The advantage of such commodity investment is the possibility to bet on rising (long position) as well as falling (short position) commodity prices depending on the investor’s market expectation. The disadvantage is the high risk because of the high short-term volatility of the commodity prices.

To note that accessing commodities via the futures market (e.g. in index form) is very different from investing in corporate securities. The economic function of corporate securities (stocks and bonds) is to raise external resources for the firm. Historically, equity or debt ownership of firms specializing in direct commodity market production was the principal means of obtaining claims on commodity investment. These claims represent the discounted value of cash flows over very long periods of time. Their value depends on decisions of the management and the expected discount rate. Therefore, investors are bearing the risk that the future cash flow of the firm may be low and are compensated for these risks with a premium over the expected risk-free yield. Commodity futures do not raise resources for firms to invest. They rather allow firms to obtain an insurance for the future value of their outputs or inputs. Investors in commodity futures receive compensation for bearing the risk of short-term commodity price fluctuations.

Furthermore, commodity futures are **short maturity** claims on real assets, and not claims on long-lived corporations. And unlike financial assets, many commodities show seasonality in price levels and volatilities.[30]

To be summarised, direct commodity investment or commodity futures are definitely the principal means by which the investor can obtain exposure to commodity price movements whereas investment in commodity futures possesses a substantial advantage of low transaction costs.

[30] Cf. Gorton, G./Rouwenhoorst , K.G. (2004): p. 2

4 Investments in Commodity Futures Indices

4.1 Comparative Analysis and Choice of Future-Based Index

Recent academic research has highlighted the advantages of investing in diversified baskets of commodity futures, which may provide investors with exposure to the benefits of commodity investment without the **inconvenience of taking delivery of the underlying physical products**.[31] To analyse a passive investment strategy, we will focus on investable indices.

A commodity index measures the returns of a passive investment strategy which has the following characteristics:[32]

(1) it allows only long positions in commodity futures,

(2) it uses commodity futures only,

(3) the futures positions are fully collateralised,

(4) it allocates passively among a variety of commodity futures without any active appraisal and selection of individual commodities.

A commodity index should fairly represent the importance of a diversified group of commodities in a form of a commodity basket to the world economy. Exchange-traded commodity markets are evolving rapidly. Today's largest commodity futures sector, the energy market, exists for only twenty years. Natural gas futures trading began in 1990. This evolution creates a potential obstacle for the creation of a **stable** commodity benchmark. Unlike, for example, broad-based equity indices, which often include hundreds or thousands of component stocks, the available universe of commodity futures is more limited. For some indices a fundamental change in their structure and rules of single commodities inclusion took place over time.[33] However, the predictability of future index behaviour decreases if the composition of an index changes materially from year to year.

At the same time, a commodity index must evolve to accommodate changes in the markets over time through regular re-weighting and rebalancing which should help the index to respond smoothly to futures market developments.

One of the most attractive aspects of commodity investment today is that there are a number of passive commodity-futures-based indices that are fully investable. In addition to providing a simple method of accessing the commodity returns, commodity indices have a number of other uses. They are a source of information on cash commodity and futures commodity market trends. They are used as performance benchmarks for the evaluation of commodity trading

[31] Cf. Moncur, G (2005): p. 1
[32] Cf. Greer, R.J. (2005): p. 25
[33] For example, the structure of RJ/CRB has been revised ten times since 1957.

advisors (CTA), and provide a historical track record useful in developing asset allocation strategies. Commodity indices attempt to replicate the return available by holding long positions in commodities as a whole, or separately as long positions in agricultural, metal, energy, or livestock investment.[34]

There are a number of various commodity indices. In this comparative analysis only six commodity indices are included: Reuters/Jefferies Commodity Research Bureau Index (RJ/CRB), Goldman Sachs Commodity Index (GSCI), Dow Jones AIG Commodity Index (DJAIGCI), Rogers' International Commodity Index (RICI), Deutsche Bank Commodity Index (DBCI), and Standard & Poor's Commodity Index (SPCI). These indices provide returns comparable to passive long positions in listed commodity futures contracts.

In Exhibit 3 a detailed comparison of all introduced indices is shown. The statistics show that GSCI and Dow Jones AIG became the dominant commodity benchmarks for investors, and thus of practical importance within a passive investment strategy. Both of them are fully investable, and most passive investment products (structured products, derivatives, funds) are based on these two indices. According to the Tiberius Asset Management, an estimated USD 55bn are invested in or benchmarked to the GSCI as of March 2005. The DJ-AIG-based investments account for USD 23bn.[35]

Exhibit 3: Comparison of Commodity Indices

Emittent	**Goldman Sachs**	**Dow Jones AIG**	**Commodity Research Bureau**	**Standard & Poor's**	**Deutsche Bank**	**Roger International**
Index	GSCI	DJAIG	RJ/CRB	SPCI	DBLCI	RICI
Year of market introduction	1991	1998	1957	Aug-01	Feb-03	1998
Retrograde calculation till	01/01/1970	01/01/1991	28/09/1956	04/11/1927	29/01/1988	31/07/1998
Index futures traded on the ...	CME	CBOT	NYBOT	not investable	investable (e.g. ETFs)	investable
Number of single commodities	24	19	17	17	6	35
Objective weightings	yes	yes	yes	yes	no	no
Maximum weightings	no	yes	yes	yes	no	no
Reweighting intervals	annual	annual	10 times in 34 years	annually	annualy	annual
Reweighting criteria for single commodities	worldwide production average (USD value) over the last 5 years	1) contract liquidity 2) dollar-adjusted production data	four-tiered approach with fixed weightings	constant dollar value of commercial open interest in futures markets	contract liquidity	contract liquidity
Rebalancing Intervals	annually	annually	monthly	real-time	monthly/annually	monthly
Gold included?	yes	yes	yes	no	yes	yes
Gold weighting	1.86%	6.22%	6%	-	10%	3%
Commodity with the highest weighting	Crude Oil	Crude Oil	Crude Oil	Natural Gas	Crude Oil	Crude Oil
Weighting of this commodity	45.99%	12.78%	23%	17.65%	35%	35%
Calculation methode	arithmetically	arithmetically	arithmetically	geometrically calculated price index		arithmetically
Estimated investment volume (Source: Tiberius AM)	USD 55bn	USD 23bn	USD 1bn	-	USD 5.4bn	USD 3.5bn

Source: own summary

Summarising the pros and cons of the indices, the advantage of a very long data history of the RJ/CRB index can be noted. However, because of numerous revisions in the weighting system the picture of the commodity market, as presented by the index, is distorted. A further disadvantage is the fact that the RJ-CRB is only calculated as a total return index which makes it impossible to analyse three single return components.

[34] Cf. CISDM (2005): p. 12

[35] Cf. Mezger, M./Eibl, C. (2006): pp. 20

The advantage of the GSCI is its relatively long data history. A disadvantage of the main GSCI index is its low exposure to the price development in the precious metals sector (only 2,13% as of January 2006). It is advisable to use a precious metal index as an additional benchmark in order to cover this sector. Some authors have pointed out the energy bias of the index as a disadvantage, but this high energy proportion clearly mirrors the importance of the energy sector in the economy.

Concerning the DJ-AIG Commodity index, it can be noted that this index is reasonably weighted across all commodity sectors and provides a sufficient data history.

The slight difference between the GSCI and DJ-AIGCI should however be remarked upon. The GSCI and DJ-AIGCI production data, although a useful measure of economic importance, may underestimate the economic significance of storable commodities (e.g. gold) at the expense of relatively non-storable commodities (e.g. live cattle). Production data alone also may underestimate the investment value that financial market participants place on certain commodities. Gold clearly illustrates the potential shortcomings of exclusive reliance on production data (like in the GSCI) and the greater balance provided by reliance on liquidity data (like in the DJ-AIGCI).

It is very important to note the change in the relative weights. For example for an original GSCI, only four contracts existed (cattle, corn, soybeans, wheat) with a 50% weight in cattle up until 1970. The index is changing over time. As the investor can not influence the re-weighting of the components, we assume the affects will continue in the future. These weights have now dramatically changed as can be seen in Exhibit 4, summarising the weighting structure of the four most important indices.

Exhibit 4: Single Constituents of Commodity Indices (as of January 2006)

	Dow Jones AIG Commodity Index	Goldman Sachs Commodity Index	Roger International Commodity Index	Reuters Jefferies CRB
Energy	**33.00%**	**75.48%**	**44.00%**	**39.00%**
Crude Oil	12.78%	45.99%	35.00%	23.00%
Heating Oil	3.85%	8.26%	3.00%	5.00%
Natural Gas	12.32%	8.34%	3.00%	6.00%
Unleaded Gas	4.05%	8.45%	3.00%	5.00%
Gasöl (IPE)		4.44%		
Industrial Metals	**18.09%**	**8.89%**	**14.00%**	**13.00%**
Aluminum	6.85%	3.16%	4.00%	6.00%
Copper	5.88%	3.62%	4.00%	6.00%
Lead		0.28%	2.00%	
Nickel	2.66%	0.77%	1.00%	1.00%
Tin			1.00%	
Zinc	2.70%	1.06%	2.00%	
Precious Metals	**8.22%**	**2.13%**	**7.10%**	**7.00%**
Gold	6.22%	1.86%	3.00%	6.00%
Silver	2.00%	0.27%	2.00%	1.00%
Platinum			1.80%	
Palladium			0.30%	
Agricultural	**30.24%**	**9.72%**	**30.90%**	**34.00%**
Azuki Beans			0.50%	
Barley			0.27%	
Canola (Rapeseed)			0.67%	
Coffee	2.93%	0.64%	2.00%	5.00%
Cocoa		0.15%	1.00%	5.00%
Corn	5.87%	2.10%	4.75%	6.00%
Cotton	3.16%	0.77%	4.00%	5.00%
Oats			0.50%	
Orange Juice			0.66%	1.00%
Rice			0.50%	
Rubber			1.00%	
Silk			0.05%	
Soybean Oil	2.77%		2.00%	
Soybeans	7.77%	1.27%	3.75%	6.00%
Sugar	2.97%	1.84%	2.00%	5.00%
Wheat	4.77%	2.95%	7.00%	1.00%
Wool			0.25%	
Livestock	**10.45%**	**3.78%**	**3.00%**	**7.00%**
Lean Hogs	4.35%	1.37%	1.00%	1.00%
Live Cattle	6.09%	1.85%	2.00%	6.00%
Feeder Cattle		0.56%		
Other	**0.00%**	**0.00%**	**1.00%**	**0.00%**
Lumber			1.00%	
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Source: own summary

Taking the above mentioned substantial disadvantages of RJ-CRB and the pros and cons of the GSCI and DJ-AIGCI into consideration, only these two indices will be considered in the further analyses.

It should be noted that the performance histories of commodity-futures-based indices are longer than the trading histories of the indices. But making strategic asset allocation decisions, many investors will use the complete history of returns, even if some of the history has been backfilled. For these commodity indices with subjective choices of weights, the investor needs to exercise caution. For instance, the GSCI has been traded since 1992, yet its performance history has been backfilled to 1969. From 1969 to 1991, the GSCI had a compound annual return of 15.3%, beating the 11.6% return for the S&P 500. From 1991 to May 2004 however, the compound annualised return of the GSCI was 7.0% and the S&P 500 had a return of 10.4%. The allegation cannot be completely refuted that the GSCI weights were determined to convince investors that the commodity-futures-based index was able to outperform stocks.[36]

The historical performance of the DJ AIG index potentially suffers from a similar construction bias as it has been traded since 1998 and its history goes back to 1991. From the inception of the performance history of the DJ AIG Commodity Index to its first trade date in July of 1998, the DJ AIG index had a compound annualised return of 4.1% while the GSCI only had a return of 0.5%. Theoretically, it can be assumed that the DJ AIG index was created with an emphasis on demonstrating hypothetical historical outperformance relative to the GSCI and to respond to some investors· concerns about the high weighting of energy.[37]

Depending on the preferences of a portfolio manager with regard to an emphasis on special commodity sectors (e.g. energy, industrial metals or agriculture) an appropriate index can also be chosen. The point to be considered is that an index as a benchmark for a commodity asset class should be liquid and broadly diversified across commodities.

4.2 Backwardation and Contango

For some commodities it has been observed that their future prices are always or the most time below spot prices. This phenomenon in the shape of the term structure curve[38] is called **backwardation.** In case of **strong backwardation** future prices are below spot prices. **Weak backwardation** occurs if discounted future prices are below spot prices.

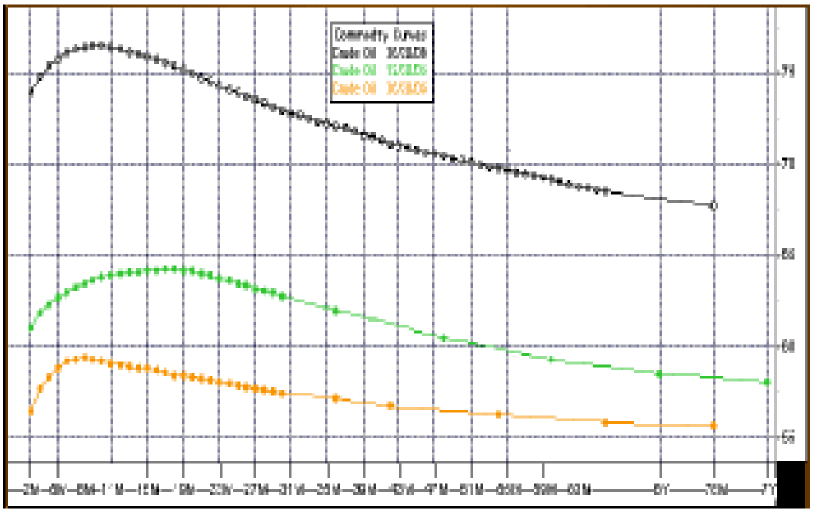
[36] Cf. Erb, C.B./ Harvey, C.R. (2005): p. 6
[37] Cf. Erb, C.B./ Harvey, C.R.(2005): p. 6
[38] The term structure is defined as a relationship between the spot price and the future prices at any delivery date. Cf. Lautier, D. (2005): p. 42

Litzenberger and Rabinowitz explained this phenomenon with the existence of "real options under uncertainty" depicting in their analysis that commodity production occurs only if discounted futures are below spot prices.[39]

Therefore, the backwardation is often explained by an expected better supply situation in the future, and that the supply-demand mechanism regulates and reduces prices. But according to Keynes, a discount on the spot price is a risk premium to a commodity futures investor for bearing the volatile commodity price risk. The investor provides a **commodity price insurance** to a commodity holder against an **insurance premium** payment.[40]

Exhibit 5 illustrates a set of futures curves for oil which are in backwardation.

Exhibit 5: Crude Oil Term Structure Curve in Backwardation



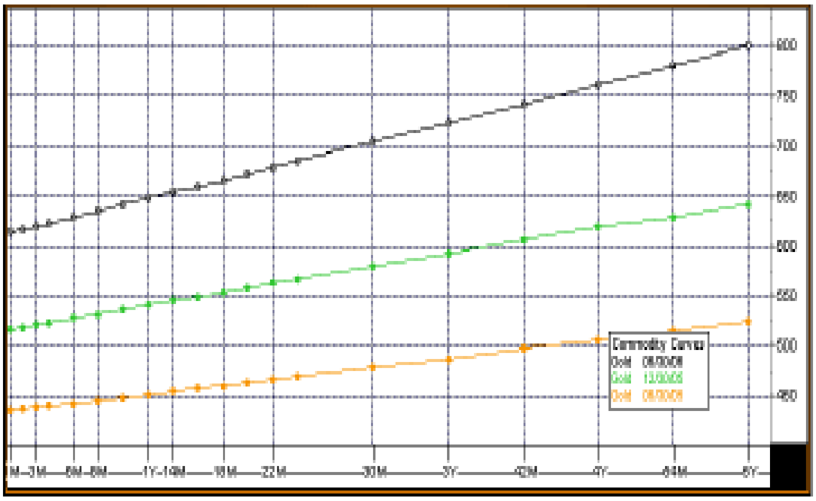
Source: Bloomberg

Historically, crude oil futures have been about 66% of the time in backwardation.[41]

When spot prices are below future prices, such a situation is called **contango** (cf. Exhibit 6). The existence of contango can be explained in terms of interest and commodity storage costs till the future maturity date.[42]

[39] Cf. Litzenberger, R./Rabinowitz, N. (1995): pp. 1517ff.
[40] Cf. Keynes, J.M. (1934): pp. 130ff.
[41] Cf. Erb, C.B./Harvey, C.R. (2006): p. 78
[42] Cf. Moncur, G./Kettle, P. (2005): p. 1

Exhibit 6: Gold Term Structure Curve in Contango



Source: Bloomberg

Historically, gold as well as silver have always been in contango.[43] Since 2002, platinum has been in backwardation around 60% of the time. A downwards sloping term structure curve for base metals occurred only in 30% of the cases in the past 20 years, but Moncur and Kettle found out that since 2002 the term curves for industrial metals were generally in backwardation.[44] It is of note that the GSCI is majority-weighted in commodity futures contracts that are typically in backwardation.

Besides the Keynes' insurance perspective, three other explanatory theoretical frameworks for backwardation and contango have been proposed: the hedging pressure hypothesis, the theory of storage, and the "weather-fear-premium-concept" which will be described in the following sections.

4.2.1 Insurance Perspective in the Theory of Normal Backwardation

In 1934, Keynes introduced his theory of "normal backwardation". His insight was that commodity futures allow companies operating in the commodity sector to hedge their commodity price exposures, and because hedging is a form of insurance, hedgers must offer investors in long only commodity futures an **insurance premium**. If this risk premium is large enough, returns of commodity futures could be similar to those of equities. In Keynes' theory of normal backwardation, the futures price for a commodity should be less than the expected spot price in the future. If today's futures price is below the spot price in the future, then, as the futures price converges toward the spot price at maturity, roll returns should be positive.[45]

[43] Cf. Erb, C.B./Harvey, C.R. (2006): p. 78
[44] Cf. Moncur, G./Kettle, P. (2005): pp. 2ff.
[45] Cf. Keynes J.M. (1934): p. 143

However, this theory has a disadvantage. Because the expected future spot price is impossible to predict, normal backwardation is not observable ex-ante. Normal backwardation is primarily a belief that long-only investors in commodity futures should receive a positive excess rate of return in form of an insurance premium. Therefore, historical evidence of positive roll returns for individual commodity futures could be a good indicator of the existence of normal backwardation. In order to test for the presence of normal backwardation risk premiums in individual commodity futures, Kolb (1992) examined 29 futures contracts and concluded that "normal backwardation is not normal" [46] Specifically, he noted that 9 commodities exhibited statistically significant positive returns, 4 had statistically significant negative returns, and the remaining 16 returns were not statistically significant. His work showed, however, that some commodity futures have positive returns and some commodity futures have negative returns. Because normal backwardation suggests that all commodity futures should have positive returns, Kolb's work indicates the challenge in proving the existence of normal backwardation. Another disadvantage of the Keynes' theory is the fact that when physical stocks are invoked to explain the relationship between spot and futures prices, interpreting backwardation becomes difficult.

4.2.2 Hedging Pressure Hypothesis

This hypothesis is an attempt to explain the lack of consistent empirical support for the theory of normal backwardation. According to the Keynes' theory of normal backwardation hedgers, having a long position in the underlying commodity, seek to mitigate the impact of commodity price fluctuations by selling commodity futures short. As a result, the futures price is expected to rise over time, which provides an inducement for investors to go long commodity futures. Both backwardated commodities, where the spot price is greater than the futures price, and commodities in contango, where the spot price is less than the futures price, may have risk premiums if backwardation holds when hedgers are net short futures and contango holds when hedgers are net long futures. That corresponds with the fact that commodity producers are often forced to hedge the inventories, but the investors need a return in order to be persuaded to enter these markets and take risk. [47]

A persistent return results from taking a position on the other **side of commercial hedge pressure**. [48] The side of the commercial hedge pressures varies over time, so that in the grains markets there have historically been seasonal periods when commercial hedging tends to be long rather than short. [49]

It could be distinguished between markets that provide a hedge for producers (markets in backwardation) and markets that provide a hedge for consumers (markets in contango). A commodity producer such as Exxon, whose business has to be long oil, can reduce exposure to oil price fluctuations by being short crude oil futures. Hedging by risk-averse producers causes futures prices to be below the expected spot rate in the future. A manufacturer such as

[46] Cf. Kolb, R.W. (1992): pp. 75ff.
[47] Cf. Greer, R.J. (2000): pp. 47f.
[48] Cf. Carter, C.A./Rausser, G.C./Schmitz, A. (1983): p.324; Erb, C.B./Harvey, C.R. (2006): p. 77
[49] Cf. Till,H./Eagleeye, J. (2005): p. 44

Boeing is a consumer of aluminium, so it is short aluminium and can reduce the impact of aluminium price fluctuations by purchasing aluminium futures. Hedging by risk-averse consumers causes futures prices to be higher than the expected spot rate in the future. In this example, Exxon is willing to sell oil futures at an expected loss and Boeing is willing to purchase aluminium futures at an expected loss. As a result, investors receive a risk premium, a positive roll return, for going long backwardated commodity futures and for going short contangoed. This line of reasoning suggests that a portfolio that consists of long backwardated futures and short contangoed futures is an attractive way to allocate capital. Both normal backwardation and the hedging pressure hypothesis reflect a view that commodity futures are a means of risk transfer and that the providers of risk capital charge an insurance premium. The hedging pressure hypothesis is more flexible than the theory of normal backwardation because it does not presume that hedgers only go short futures contracts. However, without a reliable measure of hedging pressure, investors find this concept to be of limited practical value. [50]

4.2.3 Theory of Storage and Convenience Yield

The Theory of Storage helps to explain why certain commodity futures contracts typically trade in backwardation and others do not. While energy markets are typically characterised by backwardated markets, this is often not the case for the precious and industrial metals' markets. In normal market conditions, the forward price for industrial metals tends to rise as maturity increases, i.e. the market is in contango. These differing term structures between the energy and metals markets can be explained by the Theory of Storage and the existence of convenience yield.

The specific commodity futures contracts that normally trade in backwardation are futures on commodities with difficult storage situations. For these commodities, either storage is impossible as for live cattle, prohibitively expensive as for copper, or producers decide that it is much cheaper to leave the commodity in the ground rather than to store it above ground as for gold ("real option"). [51]

The existence of storage can however act as a dampener on price volatility because it provides an additional lever in order to balance supply and demand. If the commodity's supply exceeds its demand, it can be stored, and vice versa. If too little of a commodity is produced, the stocks can be used. Price does not need to be adjusted in order to limit demand. In contrast, for commodities with difficult storage situations prices have to balance supply and demand, leading to very volatile spot prices. A defining feature of such commodities is the long lead-time between the production decision and the actual production of the commodity. It is impossible to exactly foresee what the demand will be by the time the commodity is produced. This is why supply and demand will frequently be out of balance, leading to a large amount of price volatility for these commodities. [52]

[50] Erb, C.B./Harvey, C.R. (2006): pp. 77f.
[51] Cf. Till, H./Eagleeye, J. (2003): pp. 9ff.
[52] Cf. Till, H., Eagleeye, J. (2003): pp. 9ff.

Various authors confirmed that backwardation is natural for crude oil, gasoline, live cattle, live hogs, soybean meal, and copper. All these are commodities with "difficult storage situations.[53] Of note again is that the GSCI is heavily weighted in commodities that have difficult storage situations.

The Theory of Storage focuses on the role that inventories of commodities play in the determination of commodity futures prices. In this framework, inventories allow producers to avoid stock-outs, production disruptions and the costs of frequent supply orders. With sufficient inventories there is a small likelihood that a production disruption will affect prices, and vice versa. As a result, having a level of inventories that will reduce the impact of production disruptions is beneficial. This benefit is called **convenience yield** which conceptually links **desired inventories** with commodity futures prices. The convenience yield is high when desired inventories are low and is low when desired inventories are high.[54]

In the Theory of Storage, the price of a commodity futures contract is driven by storage costs, the interest cost, and the convenience yield:

Future Price = Spot Price + Interest Cost – (Convenience Yield –Storage Cost).

The Theory of Storage splits the difference between the futures price and the spot price into the forgone interest from purchasing and storing the commodity, storage costs and the convenience yield on the inventory. Convenience yield reflects an embedded consumption timing option in holding a storable commodity. If, for instance, inventories are plentiful and both storage costs and the convenience yield are zero, the difference between the spot price of a commodity and the futures price will be the interest cost until the maturity of the contract.[55]

As the difference between spot and future price is the roll return, the convenience yield can also presented as follows:

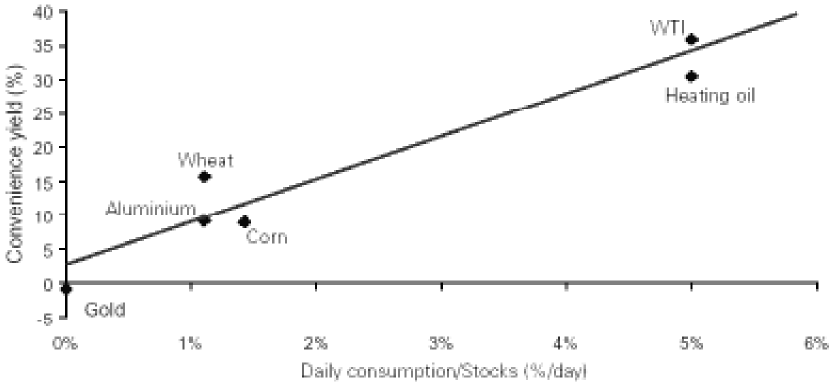
Convenience Yield = Roll Return + Storage Cost + Interest Cost.

By observing, or estimating a high convenience yield, one can infer that desired inventories are low as in tightening market conditions consumers attach a greater benefit to the physical ownership of a commodity. The best example for that is oil. As a result, the convenience yield can be thought of as a risk premium linked to inventory levels that helps explain observed futures prices. The convenience yield suggests that inventories may be low for difficult-to-store commodities; as a result, those commodities may have high convenience yields, and vice versa.[56]

Furthermore, there is a positive relationship between the convenience yield and the consumption of stock per day across a number of commodity markets highlighted in Exhibit 7.

[53] Cf. Kolb, R.W. (1996): pp.75ff.; Erb, C.B./Harvey, C.R. (2006): pp. 78
[54] Cf. Lautier, D. (2005): p.44; Erb, C.B./Harvey, C.R. (2006): p. 78
[55] Cf. Erb, C.B./Harvey, C.R. (2006): p. 78
[56] Cf. Erb, C.B./Harvey, C.R. (2006): p. 78

Exhibit 7: Commodity Convenience Yields versus the Percentage Usage of Stocks per day (1989-2004)



Source: Lewis, M. (2005): p. 21

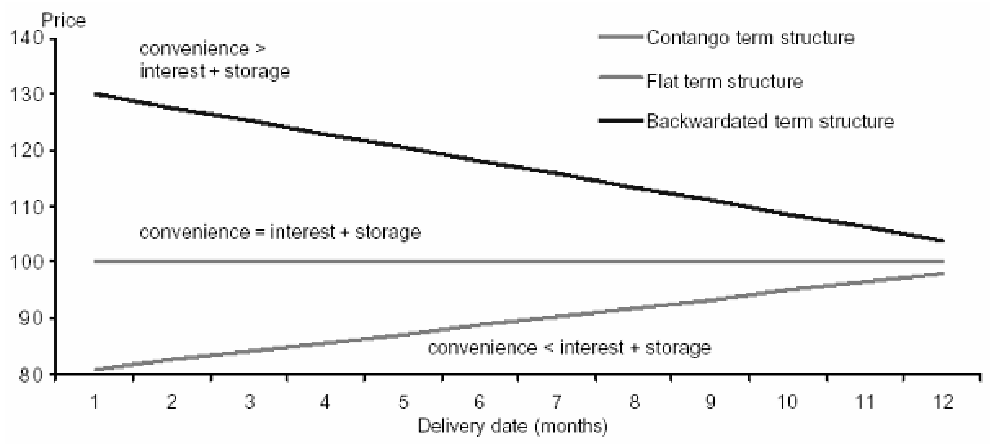
Hence, the fact that the larger the amount of daily consumption of a particular commodity compared to available inventories the greater the convenience yield. The convenience yield varies over time when there is an increase in stocks above or below the 'required level". The convenience yield is likely to rise very sharply when there is a reduction of stocks below the requirements. Such sudden changes in inventory levels due to supply or demand shocks explain why certain commodity markets move from contango to backwardation in a very short space of time.

Rearranging the formula above, an equation for the roll return is derived:

Roll Return = Convenience Yield - Storage Cost - Interest Cost.

Consequently, if the convenience yield exceeds the interest rate and storage costs, it implies a positive roll yield or a backwardated market (cf. Exhibit 8). The other way around, when the convenience yield is low and overwhelmed by interest rate and storage costs, the roll yield will be negative. A negative roll yield indicates that the spot price is lower than the futures price and is a typical feature of the precious and some industrial metals market.

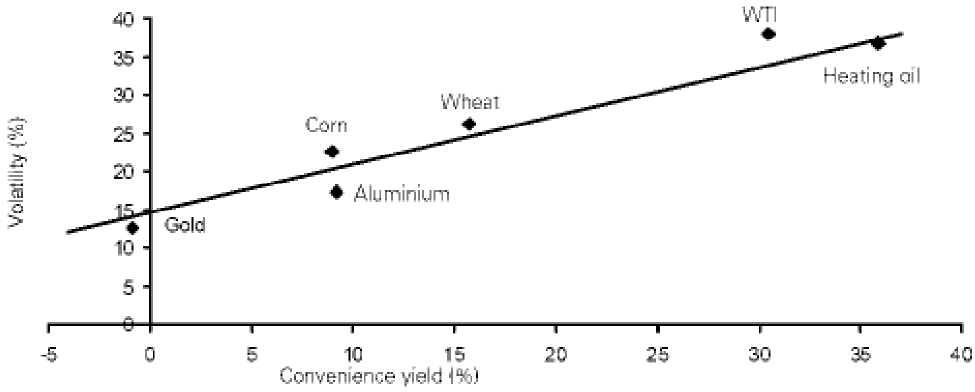
Exhibit 8: Commodity Curves & Convenience Yields



Source: Lewis, M. (2005): p.22

In 1987-1988, Fama and French performed tests of the Theory of Storage and presented empirical evidence that in periods of increasing volatility and risk, convenience yields increase for a wide variety of metals prices, e.g. aluminium, copper, nickel and lead (business cycle approach).[57] This insight is also confirmed for other commodities by the recent study of the Deutsche Bank whose results are presented in Exhibit 9.

Exhibit 9: Commodity Volatility and Convenience Yields (1989-2004)



Source: Lewis, M. (2005): p.22

As a result of the Theory of Storage and the concept of convenience yield it can be noted, that “scarcity” is a driving factor for the commodity futures prices which is indicated by the futures curve’s term structure.[58]

4.2.4 Weather-Fear-Premium

Beside “scarcity”, there exists another source of systematic returns in the futures markets due to the so called “weather premium.” A futures price sometimes embeds a “fear premium” due to upcoming, meaningful but uncertain weather events that can have a dramatical impact on the supply or demand of a commodity. That is why the corn futures are often in contango.[59]

In this class of trades, a futures price is systematically too high, reflecting the uncertainty of an upcoming weather event so that based on an analysis of historical data they can make statistically significant profits by being short the commodity futures contract during the relevant time period.[60] In 2000, Till provided examples of weather-fear premium in the grain, and natural gas futures markets.[61] However, the continuous enhancement of weather forecasting techniques reduces such kind of futures returns.

[57] Cf. Fama, E.F./French, K.R. (1987): pp. 55ff.; Fama, E.F./French, K.R. (1998): pp. 1075ff.
[58] Cf. Till, H./Eagleeye, J. (2003): p. 22
[59] Cf. Till, H./Eagleeye, J. (2005): p. 47
[60] Cf. Till, H. (2000a): p. 53; Till. H./Eagleeye, J. (2005): p. 47
[61] Cf. Till, H. (2000b): pp. 75ff.

4.3 Return Sources of Commodity Futures-Based Indices

Fully collateralised future-contracts-based commodity indices have therefore three separate sources of return: the spot return, the collateral return, and the roll return.

Spot (or price) return derives from the change in the spot price of the commodity over time. Fluctuations in commodity prices as a consequence of economic forces provides a significant yield part of the direct commodity investment because the commodity cash prices benefit from periods of unexpected inflation, whereas stocks and bonds suffer. As a result, commodities provide a positive return while other asset classes decrease in value. This premise was successfully tested in a study of the Center for International Securities and Derivatives Markets (CISDM) in 2005 by calculating the correlation of spot commodity index returns (as well as stock, bond, hedge fund, and real estate returns) with a proxy for unexpected inflation in form of the monthly change in the rate of inflation.[62]

Collateral return assumes that the full value of the underlying futures contracts is invested at a risk-free interest rate, for example in Treasury bills.[63]

A kind of the unique return source of a commodity-futures-based index is so called **roll yield**. This kind of return derives from the phenomenon of backwardation. Unlike equities, which entitle the holder to a continuing stake in a corporation, commodity futures contracts specify an expiration and delivery date for the underlying physical commodity. In order to avoid delivery and maintain a long commodity futures position, expiring nearby contracts must be sold and next-to expire contracts that have not yet reached their delivery period must be purchased. This process is known as "rolling" a future's position. All commodity indices are therefore called "rolling indices".

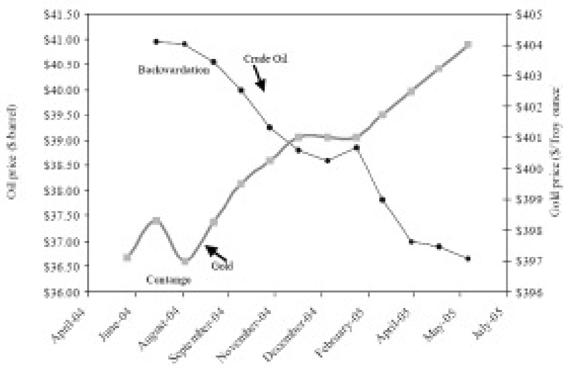
The **roll return** is the change in the price of the nearby futures contract and arises from the **rolling long futures positions** forward through time. In the futures market, a futures contract price converges to the spot price. Typically, the current spot price is the futures contract with the shortest time to maturity: the nearby futures contract. The relationship between futures prices and the maturity of futures contracts is illustrated by the **term structure curve of futures prices**. If the term structure of futures prices is upward sloping: the futures price is greater than the spot price (contango), an investor "rolls" from a lower priced expiring contract into a higher priced next nearest futures contract. In a contango market, an investor continuously locks in losses from the futures contracts converging to a lower spot price.[64] The roll return is then negative.

If the term structure of futures prices is downward sloping (backwardation), an investor "rolls" from a higher priced expiring contract into a lower priced next nearest futures contract. When the futures market is backwardated, and hence the commodity futures contract price is less than the current spot price, and there is no change in the spot price over time, the futures

[62] Cf. CISDM (2005): p. 16
[63] Cf. CISDM (2005): p. 12
[64] Cf. Till, H./Eagleeye, J. (2003): p. 5

investor realizes a **positive roll yield** equal to the difference in percentage between the spot and futures price. Roll yield captures a liquidity premium through an increased convenience yield in periods of high volatility of the underlying due to demand and supply shocks. A major consequence of a declining term structure of forward prices for investment in commodity futures is the opportunity **to capture a positive roll return** as investment in expiring contracts is moved to cheaper, new outstanding contracts.[65] This suggests that the term structure of futures prices drives the roll return.[66] Exhibit 10 illustrates the term structure of futures prices for crude oil and gold at the end of May 2004.

Exhibit 10: Term Structure of Commodity Prices, as of May 30, 2004



Source: Erb, C.B./Harvey, C.R. (2005): p. 14

In Exhibit 11 all three return components of the Goldman Sachs and Dow Jones-AIG Commodity Indices are presented.

Exhibit 11: Return Sources of the GSCI and DJAIGCI

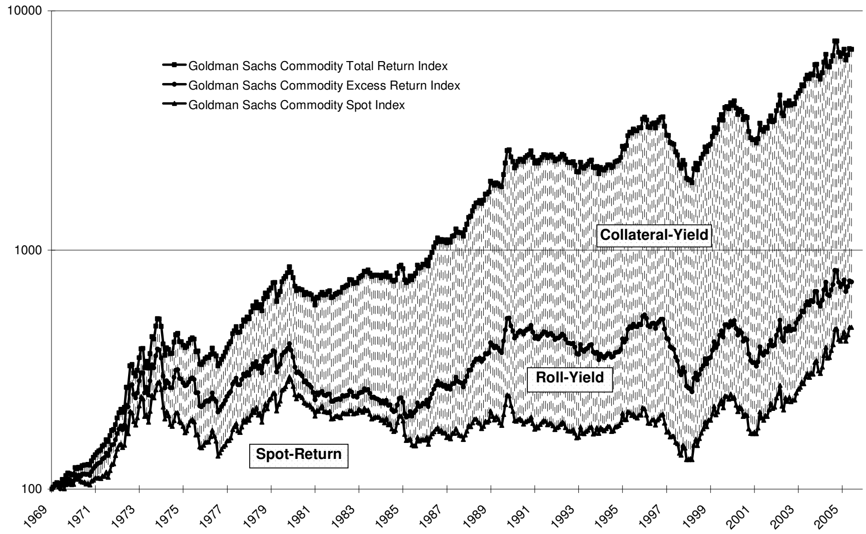
Period	Treasury Bills (Collateral Return)	GSCI Spot Return	GSCI Roll Return	GSCI Total Return	DJ-AIG Spot Return	DG AIG Roll Return	DG AIG Total Return
1970-2006							
Annualised historical average	6.19%	4.28%	1.20%	11.67%			
1970-1980							
Annualised historical average	7.04%	9.00%	2.54%	18.58%			
1981-1990							
Annualised historical average	8.71%	-2.42%	4.96%	11.25%			
1991-2000							
Annualised historical average	4.89%	1.25%	-0.66%	5.48%	3.63%	-1.65%	6.87%
1991-2006							
Annualised historical average	3.95%	5.25%	-2.19%	7.01%	7.44%	-3.01%	8.38%
2001-2006							
Annualised historical average	2.34%	12.64%	-5.02%	9.96%	14.47%	-5.52%	11.29%

Source: own calculations

[65] Cf. CISDM (2005): p. 11; Litzenberger, R./Rabinowitz, N. (1995): pp. 1517ff.
[66] Cf. Erb, C.B./Harvey, C.R. (2005): p. 14

It is of note that various commodities provide different spot and roll yields. So, the roll yield of the energy commodities is six times as high as the spot yield. The roll yield of most base and precious metals is negative.[6 7] In Exhibit 12 all three yield components for the GSCI are presented graphically.

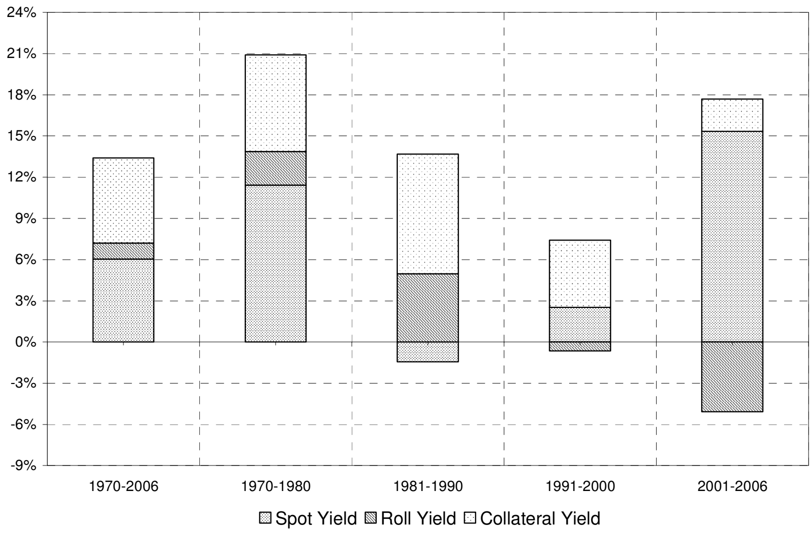
Exhibit 12: Return Sources of the GSCI (1969-Mai 2006)



Source: own calculation

In Exhibit 13 the development of return components over different decades is presented.

Exhibit 13: Return Sources of the GSCI (1969-Mai 2006)



Source: own calculation

[6 7] Cf. Mezger,M./Eibl, C. (2005): p. 11

Accordingly, there are three indices-subsets for the presented main index: **spot return index** which includes spot returns, **excess return index** which includes spot and roll returns, and **total return index** which additionally includes collateral returns.

5 Portfolio Selection Model in Consideration of Commodity-Related Investments

5.1 Idea and Assumptions of Markowitz's Portfolio Selection Model

The portfolio theory deals with the optimal allocation of a given sum of money to various investment alternatives. In the traditional portfolio theory only the expected return is the object of quantitative considerations. In contrast to the traditional portfolio theory, the modern portfolio theory according to Markowitz also takes the **risk** into account in addition to the **expected return** of an investment.[68]

The central idea of the modern portfolio theory lies in the two-dimensional return-risk-optimisation of a portfolio which means that the available amount of money is distributed on various investment alternatives in such a way that a given return with the lowest possible risk, or the highest return with a given risk will be reached.[69] The Portfolio Selection Theory of Harry M. Markowitz includes two especially important aspects in the evaluation of the return chances of single investments:

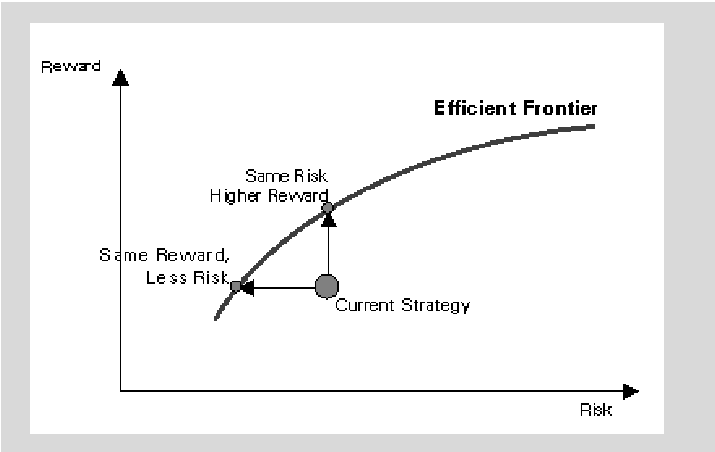
- the risks connected with the return chances of the single investments and
- the correlation between the risks linked to single investments.

As the price trend of different assets usually does not develop in completely the same direction and risks partly neutralize each other, a reduction of the total portfolio risk is possible through a diversification by various investment alternatives.[70] Consequently, the investments with a comparatively small return outlook are able to contribute to the total portfolio success by being a component of a diversified portfolio.[71] Therefore, the investment alternatives are evaluated not in isolation but always as a component of a whole portfolio in combination with other investment alternatives.[72]

[68] Cf. Markowitz, H.M. (1952): pp.77ff; Garz, H./Günther, S./Moriabadi, C. (1997): p.17; Hielscher, U. (1999): pp.52ff.; Steiner, M./Bruns, C. (2002): pp.7ff.
[69] Cf. Hielscher, U. (1999): p.54; Rudolph, B. (1995): pp. 28f.
[70] Cf. Hielscher, U. (1999): pp. 57f.
[71] Cf. Garz, H./Günther, S./Moriabadi, C. (1997): p. 17
[72] Cf. Auckenthaler, C. (1994): pp. 152f.

The result of the model application is the identification of a set of efficient portfolios which are presented by a so-called **efficient frontier** (or **efficient line**). The efficient portfolio is determined according to the parameters **expected return μ** for the *yield* and **standard deviation σ** for the *risk*. The **efficient line** is therefore the geometrical place of all efficient return-risk-combinations (cf. Exhibit 14).[73]

Exhibit 14: Minimum Variance Portfolio and Efficient Portfolios



Source: www.fiwi.uni-leipzig.de

A portfolio is efficient if there is no other portfolio which has a higher return with the same risk or the same return with lower risk.[74]

Model Assumptions

The Portfolio Selection Model is based on the **μ/σ**-Principle. The simple **μ/σ**-Principle indicates that if a decision maker can give an opinion regarding at least subjective probabilities for his decision under uncertainty, then the expected value of the probability distribution can be calculated, and it is possible to reach a decision according to the maximum expected value.[75]

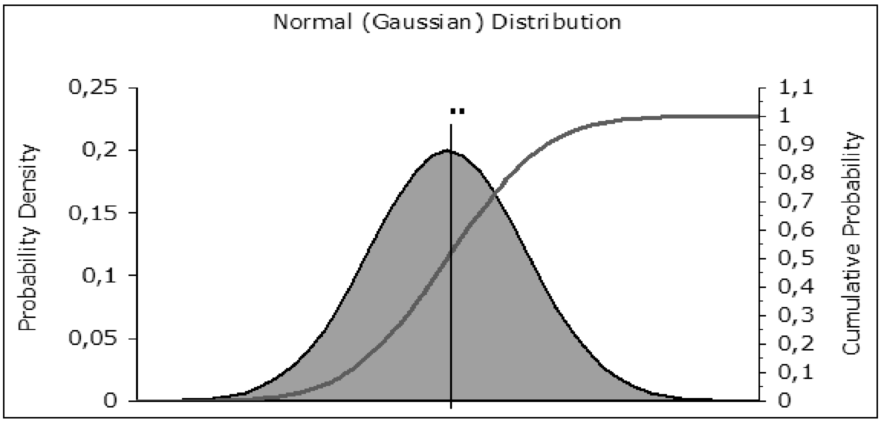
If the risk of an investment should be taken into consideration then the rule for decision-making is: in the case of risk aversion of the investor, and if the investment alternatives are supposed to have the same expected return, the alternative with a lower standard deviation is more reasonable than the alternative with a higher standard deviation (**μ/σ-principle**).[76]

[73] Cf. Rehkugler, H. (2002): p. 11
[74] Cf. Kleeberg, J.M. (1996): p. 587; Elton, E. J./Gruber, M. J. (1995): p. 70; Steiner, M./Bruns, C. (2002): p. 9.
[75] Cf. Perridon, L./Steiner, M. (2002): p. 107
[76] Cf. Perridon, L./Steiner, M. (2002): p. 109; Breuer, W./Gürtler, M./Schuhmacher, F. (1999): pp. 40ff.

This **μ/σ-principle** assumes a normal distribution of returns. The advantage of this assumption is the fact that such distribution can be characterised with only two parameters: **expected return μ** and **variance σ^2**, or rather **standard deviation σ**. [77]

The density function of the normal distribution is presented graphically by a Gaussian "bell-shaped" curve. As shown in Exhibit 15, the normal distribution is characterised by the fact that the probability of the expected return value is the highest one. The further the deviation from the expected value, the lower the probability.

Exhibit 15: Normal Distribution of Returns



Source: own calculation

Furthermore, the portfolio selection theory is based on the following basic assumptions. The approach is viewed as a **single-period** approach. The objective of the investor is utility maximisation at the end of the single holding period. That means the result of the investment in various assets is examined at the end of the period and then the following period is planned.

Within the portfolio theory it is assumed that a **perfect and efficient market** without transaction costs and taxes exists. Therefore, only the two decision parameters return and risk are considered. The investment decision is two-dimensionally based on the expected return and expected risk of an investment alternative.

The investor is **risk averse** what means that he expects the highest possible return for a given risk of an investment alternative, or he prefers the lowest possible risk for a given return of an alternative.

For the capital market a **perfect competition** is assumed which means that the investor has no influence on the price and therefore on the probability distribution of returns. As a conclusion of the assumption list, all investment alternatives can be divided into fractions. [78]

[77] Cf. Steiner, M/Bruns, C. (2002): p. 58; Kleeberg, J.M. (1995): p. 9; Neubauer, W. (1994): p. 350; Bohley, P. (1996): p. 396; Oehler, A./ Unser, M. (2002): p. 12

5.2 Other Asset Classes and Proxies Used for Modelling

This section provides a basis for further considerations within an index-based passive investment strategy. Various indices for equities and bonds will be introduced and explained.

There are three main purposes of an index:

(1) an index is an **indicator** of prices that can be used by economists and investors;

(2) an index is a **benchmark** to measure the performance of a particular asset;

(3) an index is a **trading instrument** allowing investors to obtain exposure to a particular sector.[79]

In the context of this work the role of an index as a benchmark is considered to be the most important one because in a passive investment strategy it is of substantial importance to determine which index should be used as a decision facilitator within various portfolio optimisation approaches. The purpose of an index as a trading instrument is also of practical importance because it implies a requirement of the index to be investabe.

In addition to section 4.1 in the following sections a number of indices for various asset classes (equities and bonds) will be presented and their role as possible benchmarks will be explained.

5.2.1 Equity Indices as a Benchmark

The equity market in the US is represented by the performance index **Standard & Poor's 500** (S&P 500).[80] The S&P 500 Index is the most widely used benchmark for measuring the performance of large-capitalisation US stocks. Covering almost all of the 500 largest companies ranked by market value, the S&P 500 constitutes about 83% of the market capitalisation of all widely held and regularly traded stocks on the New York, American, and NASDAQ exchanges. The Standard & Poor's 500 Performance index also includes reinvestment of all dividends, and is therefore a total return index.

The **Morgan Stanley Capital International** (MSCI) World Index measures the performance of a diverse range of national global stock markets and reproduces the worldwide equity market covering 24 developed economies, including the United States, Canada, Europe, Australia, New Zealand, and the Far East.

---

[78] Cf. Sharpe, W.F./Alexander, G.J./Bailey, J.V. (1995): pp. 167ff.; Auckenthaler, C. (1994): pp. 154f.; Perridon, L./Steiner, M. (2002): pp.2 65f.; Breuer, W./Gürtler, M./Schuhmacher, F. (1999): pp. 40ff.; Kaplan, P.D. (1998): p. 3f.

[79] Cf. Moncur, G (2005): p. 1

[80] The Bloomberg-Ticker for Standard & Poor's 500 Index is SPX.

The foundation of the various MSCI indices is a database consisting of approximately 1,500 companies listed on the stock exchanges of the 24 countries for which MSCI national indices exist.[81]

The MSCI index is a capitalization-weighted index. Furthermore, companies included in the indices replicate the industry composition of each local market, and represent a sampling of large-, medium- and small-capitalization companies from each local market, taking into account the stocks' liquidity. The inception date of the MSCI Index is January 1st, 1970.

The index is calculated daily on a price-only basis, as well as with dividends reinvested, for total return results (gross and net).[82] Net dividend reinvested indices reflect a subtraction for withholding taxes retained at the source for foreigner investors who do not benefit from a double taxation treaty.

In the further analysis these two indices, S&P 500 for the US and MSCI World, are used for the international equity market.[83]

5.2.2 Bond Indices as a Benchmark

There is a variety of indices representing the development in the bond market.

For the suitability as benchmark, a number of criteria are defined as follows:

- index composition (e.g. government bonds versus all investment grade bonds),
- region (global, USA or EU),
- rating categories,
- duration.

The choice of a benchmark for a fixed income market should match the structure of the portfolio.

For the purpose of the portfolio optimisation only composite indices for high-rated bonds (AA or better) should be used in order to eliminate a possible impact of the credit risk component which is bond inherent additional to the market risk component.

[81] The MSCI World Index consists of the following countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, Malaysia, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States.

[82] GD = total return index with gross dividends reinvested; ND = total return index with net dividends (after tax) reinvested

[83] The version of the MSCI World Index in Local Currency is used in order to eliminate the effect of the varying currency exchange rate. The Bloomberg-Ticker for MSCI World in Local Currency is MSDLWI with the introduction date January 1st, 1980.

The most widely used bond indices are calculated by Lehman Brothers, Citigroup and J.P. Morgan.

For the further analysis in a passive investment approach, the Lehman Government Bond Index will be used for the US bond market; for the international bond market the Citigroup World Government Bond Index is the chosen benchmark. As an alternative, the application of the J.P. Morgan Government Bond Index for both US and worldwide is possible.

The **Lehman Government Bond Index** is composed of the Lehman Brothers Treasury Bond Index (all public obligations of the US Treasury, excluding flower bonds and foreign-targeted issues) and the Agency Bond Index (all publicly issued debt of the US government agencies, quasi-federal corporations, and corporate debt guaranteed by the US government). The inception date of the index is December 31st, 1975. The index is calculated monthly, on a price-only and total return basis.

The **Citigroup World Government Bond Index** was constructed with the aim of choosing an all-inclusive universe of institutionally traded bonds. The index includes all fixed-rate bonds with a remaining maturity of one year or longer and with amounts outstanding of at least the equivalent of USD 25m. Those government securities that are excluded from the indices typically fall into three categories: floating- or variable-rate bonds (including index-linked bonds); securities aimed principally at non-institutional investors such as savings bonds in the United States and Canada; and private placement-type securities, for which liquidity may be poor and for which accurate information on outstanding debts, market coupon, and maturity structure may be difficult or impossible to obtain. The date of the index's inception is December 31st, 1984. The index is calculated in US dollar terms and in Local Currency terms.[84]

This index provides an accurate, replicable fixed income benchmark for market performance on a worldwide basis. The government sector dominates the market of internationally traded securities, accounting for nearly 70% of outstanding debts of governments, eurobonds, and foreign bonds denominated in the included currencies. The indices are designed to provide a comprehensive measure of the total return performance of the domestic government bond markets in each country and in the countries combined.

The **J.P. Morgan Government Bond Index** measures the performance of leading government bond markets based on total return in US currency. By including only traded issues, the index provides a realistic measure of market performance for international investors. The inception date of the index is December 31st, 1985.[85]

[84] The Bloomberg-Ticker for the Citigroup World Government Bond Index in US dollar terms is SBWGU, in Local Currency terms is SBWGL. For the US bond market also Citigroup Treasury & Government Index (SBGOV) exists, but its date of inception is January 31st 1980 (shorter history than Lehman Brothers index).

[85] For the US bond market the J.P. Morgan Global Govt Bond Local Currency US Index with the inception date December 31st, 1985 is applicable (JPMGGLTR). For the international bond market in USD terms the JPMor-

All these indices focus only on fixed income instruments with a premium "quality" rated with AAA to AA+ which allows ignoring the credit risk implied in those instruments.

The problem with all bond indices is their shorter data history compared to the existing equity and commodity indices: S&P500 is calculated since 1959, GSCI since 1970.

In the following sections the practical approaches for the passive investment strategy will be explained and some empirical results will be presented.

5.2.3 Including Commodities in the Portfolio Selection Model

5.2.4 Statistical Basics

The Markowitz-Model is based on an ex-ante-Perspective which means that for each investment the **expected return** (mean) and the **standard deviation** as dispersion measure around the mean should be estimated. In practice, it is however often impossible to determine the probabilities of the return distribution.[86] Therefore, an assumption is made that the data of the past is valid for the future.[87]

The analysis of the data observed in the past results in an average return (mean) which at the same time represents the **expected return**. In order to determine the average return, first the *continuous return* has to be calculated as a logarithmic relative value change of each single investment alternative in the observation period:

$$r_{i,t}^{s} = \ln\left[\frac{K_{i,t}}{K_{i,t-1}}\right],$$

with $r_{i,t}^{s}$ = continuous return of the investment *i* in the period *t-1* till *t*,

$K_{i,t}$ = price of the investment *i* at the time point *t*,

$K_{i,t-1}$ = price of the investment *i* at the time point *t-1*.

Formula 1: Continuous Return

gan Global Govt Bond Unhedged US exists since December 31st, 1985 (JPMGGLBL), in Local Currency since April 1st, 1998 (JPMGBRLC).

[86] The probabilities are necessary for the estimation of the expected return.

[87] Cf. Biermann, B./Grosser, K. (1999): p. 20

From the annual continuous returns of single investments an average is calculated that represents the expected return of the investment:[88]

$$\overline{r_i} = \frac{\sum_{t=1}^{S} r_{i,t}}{n},$$

with $\overline{r_i}$ = expected return of the investment *i*,[89]

n = number of values in the random sample.

Formula 2: Expected Return of a Single Investment

The continuous return is applied because it rather corresponds to the normal distribution hypothesis than the discrete return[90] The continuous returns are more likely to follow the symmetrical distribution around the mean than the discrete returns. This fact is valid especially for longer observation periods.[91] In opposition to the discrete return, the concept of the continuous return assumes that the changes of the underlying between two time points *t* and *t-1* occur in infinitesimal intervals infinitely often.[92]

The expected return of the portfolio is determined as the weighted sum of the expected returns of single investments:

$$r_{PF} = \sum_{i=1}^{n} x_i \cdot \overline{r_i},$$

with r_{PF} = expected value of the portfolio return,

x_i = weighting of the investment alternative *i* in the portfolio.

Formula 3: Expected Return of a Portfolio

As an estimation of the risk of an investment the **variance σ²** or rather the **standard deviation σ** is used. The variance is the measure for the dispersion of investment returns around its expected value, and is calculated as the sum of quadratic deviation of the continuous returns from the expected value (mean) divided by the number of the observed values.

[88] Cf. Lange, K. (1996): p.3.; Breuer, W./Gürtler, M./Schuhmacher, F. (1999): p. 48
[89] The **expected return** is described by either μ or E(r).
[90] The discrete returns are calculated according the formula: $r_{i,t}{}^{d} = \frac{K_{i,t}}{K_{i,t-1}} - 1$.
[91] Cf. Steiner, M./Bruns, C. (2002): p. 54; Lister, M. (1997): pp. 44ff.
[92] Cf. Poddig, T./Brinkmann, U./Seiler, K. (2005): p. 41

The mathematical formula for the variance estimation of a single investment alternative is the following:[93]

$$VAR_i = \sigma_i^2 = \frac{1}{n-1}\sum_{t=1}^{n}(r_{i,t}^{s} - \overline{r_i})^2,$$

with VAR_i = variance of the investment *i*,

$r_{i,t}^{s}$ = continuous return of the investment *i* for the time point *t*,

$\overline{r_i}$ = expected return of the investment *i*,

n = number of values/results in a (random) sample.

Formula 4: Variance of a Single Investment

The standard deviation σ is the squared root of the variance:[94]

$$\sigma_i = \sqrt{VAR_i} = \sqrt{\frac{\sum_{t=1}^{n}(r_{i,t}^{s} - \overline{r_i})^2}{n-1}}.$$

Formula 5: Standard Deviation of a Single Investment

In principle, it does not matter whether the standard deviation or the variance is used as a risk measure. However, the standard deviation has the advantage to be graphically presentable.[95] With the standard deviation the movements of investments' returns around their means are measured mathematically. The higher the standard deviation, the higher the risk because the wider possible returns scattered, the higher the danger that the expected return will not be reached.[96]

These two distribution parameters, the expected return and dispersion of the return are estimated from a (random) sample of the distribution and applied to the future. As the calculated values are dependent on a random sample, there are estimation errors. Observation periods which are shorter than one year make a comparison of return and risk more difficult. For the comparability of various investment alternatives an annual consideration is targeted. For this

[93] If the variance is calculated only from a small data sample, the divisor in the formula should be (n-1) instead of n. This is of especial importance if there are only few observed values. The difference decreases the larger the data sample is. Cf. Lange, K. (1996): p. 5; Poddig, T./Brinkmann, U./Seiler, K. (2005): p. 49; Breuer, W./Gürtler, M./Schuhmacher, F. (1999): p. 48

[94] Cf. Lange, K. (1996): p. 5

[95] Cf. Hielscher, U. (1999): p. 57.

[96] Cf. Hielscher, U. (1999): p. 55; Oehler, A./Unser, M. (2002): p. 12.

purpose a conversion of the return and risk measures to a longer period than one year is necessary *(annualisation)*.[97]

The annualisation of returns is relatively easy:

$$r_{p.a.}{}^{s} = r_{HD}{}^{s} \cdot \frac{T_1}{T_2},$$

with $r_{HD}{}^{s}$ = continuous return for the holding period of time,

T_1 = 1 year (expressed in time units of the period T_2),

T_2 = holding period.

Formula 6: Annualisation of Returns

The conversion rule for continuous returns is: the return of a shorter holding period can be converted to the return of a longer period by multiplying the ratio of a longer and a shorter holding period.[98]

For the annual standard deviation the following relation is valid according to the „root law“:

$$\sigma_{p.a.} = \sigma_{T_2} \cdot \sqrt{\frac{T_1}{T_2}},$$

with $\sigma_{p.a.}$ = annualised standard deviation

σ_{T_2} = standard deviation for the holding period T_2.

Formula 7: Annualisation of the Standard Deviation

If the calculation of the standard deviation is based on daily returns, the formula is: $\sqrt{250} \cdot \sigma_{T_2}$; for monthly returns the formula is: $\sqrt{12} \cdot \sigma_{T_2}$.[99]

In the following section the results of the data analysis for various asset classes will be presented. Data in the form of monthly returns was obtained for each of the indices from Bloomberg.

The variance, or rather the standard deviation are only suitable as a risk measure for single investments. They are, however, an insufficient risk measure for a portfolio. The reason lies in existing compensating effects between single components of a portfolio (correlation) which are expressed by the covariance.[100] The *covariance* expresses the statistical dependence of

[97] Cf. Lister, M. (1997): pp. 59ff.
[98] Cf. Lister, M. (1997): pp. 44ff.
[99] Cf. Steiner, M./Bruns, C. (2002): p. 61
[100] Cf. Lister, M. (1997): p. 98

the return developments of two investment alternatives, and determines the dimension of the portfolio risk reduction by a spreading of investments.[101]

It is characteristic for the variance or standard deviation that they decline if investment alternatives with not wholly positive correlated returns are combined to a portfolio. For an optimal portfolio many single investments are combined in such a way that the resulting combination shows the lowest variance or standard deviation, and therefore the lowest risk.[102] To calculate the variance or standard deviation of the whole portfolio, the diversification effects between single investments should be taken into consideration with the covariance $Cov_{i,j}$. The mathematical formula for the covariance of two investments is the following:[103]

$$Cov_{i,j} = \frac{1}{n-1}\sum_{t=1}^{n}(r_{i,t} - \overline{r_i})(r_{j,t} - \overline{r_j}), \text{ or}$$

$$Cov_{i,j} = \frac{1}{n-1}\sum_{t=1}^{n} r_{i,t} \cdot r_{j,t} - \overline{r_i} \cdot \overline{r_j},$$

with $\overline{r_i}, \overline{r_j}$ = average returns (or expected returns) of investments *i* and *j*.

Formula 8: Covariance of the Value Development of Two Investments of a Portfolio

The correlation can also be expressed through a correlation coefficient with values between –1 and +1. The correlation coefficient ρ is calculated through standardization of the covariance which includes a division of the covariance by the product of both standard deviations:[104]

$$\rho_{i,j} = \frac{Cov_{i,j}}{\sigma_i \times \sigma_j}.$$

Formula 9: Correlation Coefficient

A correlation coefficient equal +1 means that the value change of single investments is perfectly positively correlated and develops in the same direction. In this case no diversification effects exist (r*isk accumulation*).

A correlation coefficient equal 0 means that the value change of single investments is absolutely independent from each other. Therefore a risk reduction through diversification is possible (r*isk spreading*).

A correlation coefficient equal -1 means a completely negative correlation. The value change of an investment always develops in the opposite direction than the value change of another position. As a result maximal diversification effects are possible (*risk compensation, hedging*).

[101] Cf. Biermann, B./Grosser, K. (1999): p. 16; Kleeberg, J. M. (1995): p. 9; Rehkugler, H. (2002): p. 11
[102] Cf. Kleeberg, J.M. (1996): p. 587
[103] Cf. Steiner, M./Bruns, C. (2002): p. 8; Steiner, P./Uhlir, H. (2001): p. 138
[104] Cf. Steiner, M./Bruns, C. (2002): p. 10; Steiner, P./Uhlir, H. (2001): p. 138; Kleeberg, J.M. (1995): p. 10

Generally, only investments with a correlation coefficient below +1 should be combined with each other as the portfolio risk is then smaller than the average risk of all investment alternatives in the portfolio. Thus, the risk reducing effect is larger the smaller the correlation coefficient is, or the fewer the value changes of single investments are dependent on each other.

The variance of a portfolio σ_{PF}^2 is calculated under consideration of correlations $\rho_{i,j}$ between single investments:[105]

$$\sigma_{PF}{}^2 = \sum_{i=1}^{n} x_i{}^2 \sigma_i{}^2 + 2\sum_{j=1}^{n}\sum_{\substack{i=1\\ i\neq j}}^{n} x_i \cdot x_j \cdot \sigma_i \cdot \sigma_j \cdot \rho_{i,j}$$, or with the covariance:

$$\sigma_{PF}{}^2 = \sum_{i=1}^{n} x_i{}^2 \sigma_i{}^2 + 2\sum_{j=1}^{n}\sum_{\substack{i=1\\ i\neq j}}^{n} x_i \cdot x_j \cdot Cov_{i,j}\,.$$ [106]

Formula 10: Variance of a Portfolio

In the selection of decision alternatives, it is not only important to find investments with low risk, but also to include such investment alternatives that have a low correlation with other portfolio components. If the risk value of single investments is simply added up, which is only correct for a correlation of +1, the actual risk of the portfolio would be over-estimated.

5.3 Empirical Results Risk and Return

In the literature, investing in commodity futures is assumed to be as rewarding as investing in equities. In 2005, Gorton and Rouwenhorst showed that commodity futures returns are negatively correlated with equity and bond returns. They argued that this negative correlation between commodity futures and the other asset classes is due, in significant part, to a different behaviour over the business cycle. They also add that commodity futures are positively correlated with inflation, unexpected inflation, and changes in expected inflation. But they also showed that over the period July 1959 till December 2004 a portfolio of equally weighted fully collateralised commodity futures offered the same return as equities but with a lower level of volatility.[107]

The following picture presented by Erb and Harvey (cf. Exhibit 16 on the left) confirms this statement and shows that from 1969 to May 2004, the 12.2% compound annualised return of the GSCI compares favourably with an 11.2% return for the S&P500.[108] But looking at a different period in time the picture changes (cf. Exhibit 16 on the right). In 1975-2005 the GSCI provided less yield with a higher risk.

[105] Cf. Hielscher, U. (1999): p. 59

[106] Für die Portfolios, die aus nur zwei Anlagealternativen bestehen, ergibt sich beispielsweise: $\sigma_{PF}{}^2 = x_A{}^2\sigma_A{}^2 + x_B{}^2\sigma_B{}^2 + 2x_A \cdot x_B \cdot COV_{A,B}$

[107] Cf. Gorton G./Rouwenhorst G. (2005): pp. 12ff.

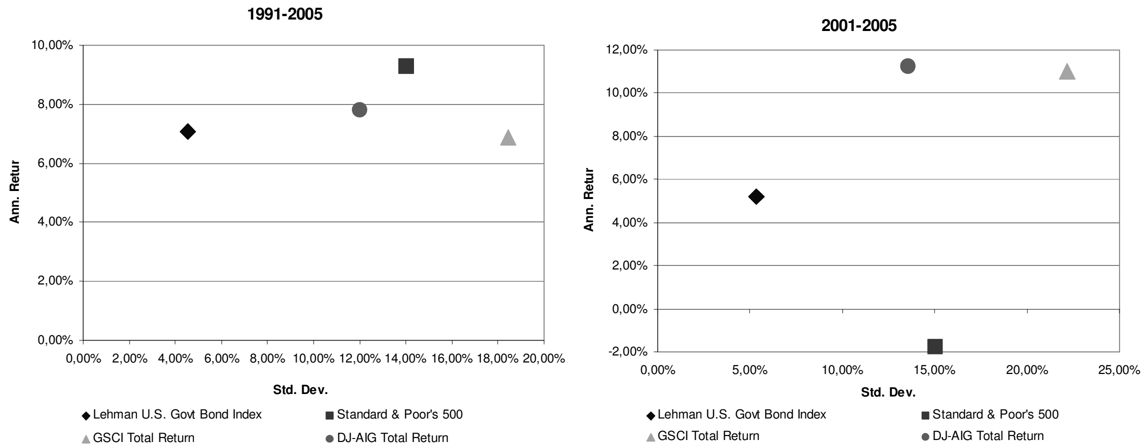
[108] Cf. Erb, C.B./Harvey, C.R. (2005): p. 2

Exhibit 16: Risk and Return of Equity, Bond and Commodity Indices

Source: Cf. Erb, C.B./Harvey, C.R. (2005): p. 2 and own calculations

Including the DJ-AIG Commodity Index and considering other time periods provides further conclusions (cf. Exhibit 17).

Exhibit 17: Risk and Return of Equity, Bond and Commodity Indices



Source: own calculations

For the period 1991-2005 the picture for the GSCI is similar to that of the period 1975-2005, while the DG-AIGCI provides better risk-adjusted returns. The period 2001-2005 was obviously the period of the "bull market" for commodities.

Thus, it is not possible to give a wholesale judgement that commodities are as good as equities, or even better. It is obvious that in order to be able to judge both asset classes, it is necessary to take into consideration risk-adjusted performance measures on one side, and also the choice of the analysis time period with the corresponding state of the economy including the current stock, bond and commodity market situation, on the other side.

In order to compare stock and commodity investments, the performance measures were calculated in 5-year intervals. The five-year intervals in the US are 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2006(*).[109] For comparison of both investments the Sharpe-Ratio as risk-adjusted performance measure is applied which shows the risk per unit of return (cf. Exhibit 18).[110]

Exhibit 18: Risk-Adjusted Performance Measures of Equities and Commodities

Period	S&P 500	GSCI TR
1975-2006(*)		
Annualised historical average return	7,21%	11,63%
Std. Dev.	15,37%	18,50%
Sharpe Ratio (6,19%)	0,07	0,29
1976-1980		
Annualised historical average return	8,18%	12,96%
Std.Dev.	14,52%	19,04%
Sharpe Ratio (~7,04%)	0,08	0,31
1981-1985		
Annualised historical average return	8,85%	1,73%
Std.Dev.	13,61%	11,10%
Sharpe Ratio (~8,71%)	0,01	-0,63
1986-1990		
Annualised historical average return	8,93%	20,69%
Std.Dev.	19,36%	15,96%
Sharpe Ratio (~8,71%)	0,01	0,75
1991-1995		
Annualised historical average return	12,47%	2,89%
Std.Dev.	9,93%	12,35%
Sharpe Ratio (~4,89%)	0,76	-0,16
1996-2000		
Annualised historical average return	15,25%	7,89%
Std.Dev.	16,14%	19,49%
Sharpe Ratio (~4,89%)	0,64	0,15
2001-2006(*)		
Annualised historical average return	-0,72%	9,95%
Std.Dev.	14,62%	23,06%
Sharpe Ratio (2,34%)	-0,21	0,33

Source: own calculations

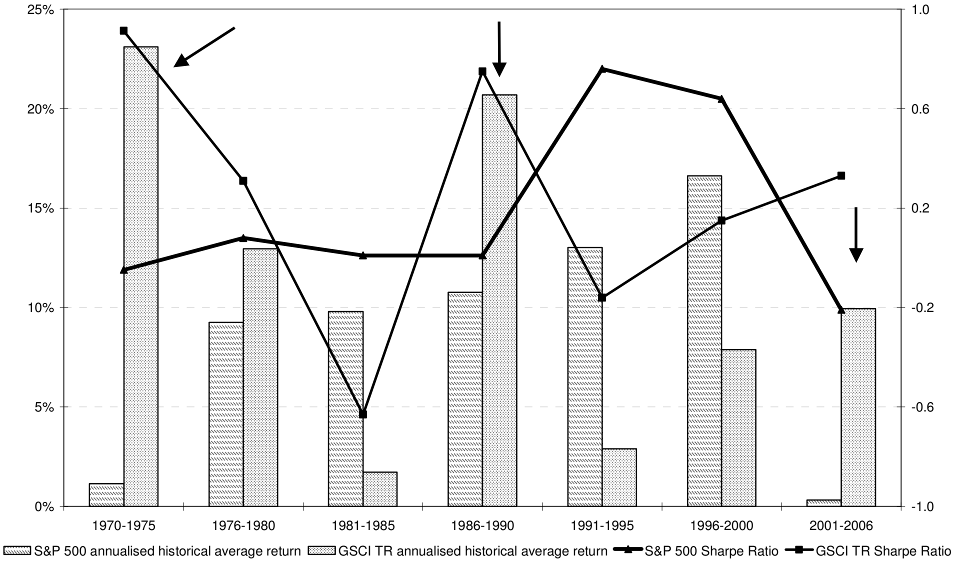
These comparisons show that for example in the period from 1975 to 2006, commodities actually provided similar returns as equities. However, considering the results in terms of Sharpe-ratio, commodities were more risky than equities in the period 1975-2006. But in the period 1986-1990 the risk-adjusted performance measures of commodities were better than those of equities. The calculations for the international finance market lead to similar results.

[109] (*)= through Mai 2006

[110] The risk-free-rate for the corresponding period is noted in the brackets in Exhibit 18.

For a better overview, the calculation results for the five-year intervals are presented graphically in Exhibit 19.

Exhibit 19: Risk-Adjusted Performance of the S&P500 and GSCI TR



Source: own calculation

In the analysis of the five-year intervals there are three interesting periods for further consideration: 1976-1980, 1986-1990 and 2001-2006 in which commodities showed a substantial outperformance compared to equities with equal or better risk-adjusted performance figures. It must be noted, however, that commodities are more volatile than equities.

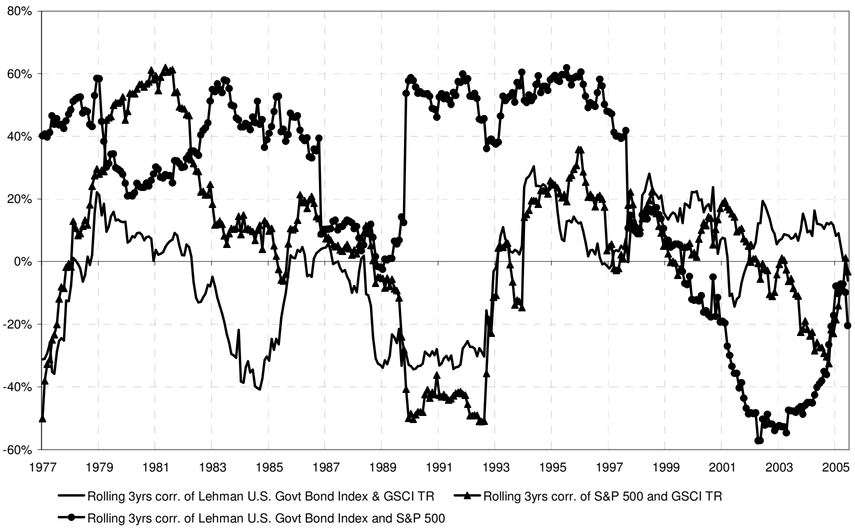
5.4 Empirical Correlation Results

It is quite possible that commodities underperform equities in absolute terms and on a risk-adjusted basis according to Sharpe-Ratio. Nevertheless, commodities may produce investment benefits when considered as an addition to a diversified portfolio.

The decision to add an investment product to an existing portfolio depends on the means and variances of the existing portfolio and the investment vehicle as well as the correlation between the portfolio and the investment vehicle. The low or negative correlations of GSCI returns with returns of the S&P 500 and Lehman Government Bond Index suggest such potential benefits.

The correlation varies over time. Exhibit 20 shows the 3-year rolling development of the correlation between commodities and equities, between commodities and bonds, and between bonds and equities for the US market in the period of 1975 to 2006.

Exhibit 20: Rolling Correlation of the Commodity, Equity and Bond Indices



Source: Bloomberg (data)

As expected the prices of real assets and nominal assets move in opposite directions or have an uncorrelated relationship.

Similarly, when considered as a global investment, the GSCI exhibited low or negative correlations with the MSCI World Index and Lehman Global Bond Index. Comparable results hold for the DJ-AIGCI.

To note that the negative correlation of commodity futures with stocks and bonds tends to increase with the holding period which suggests that the diversification benefits of commodity futures tend to be larger at longer horizons.[111]

The above relationships are reflected in the performance of investment portfolios including the GSCI and DJ-AIGCI in various proportion. When added to a domestic portfolio of stocks and bonds, the GSCI (10%) helped to reduce the standard deviation of the portfolio from 8.14% to 7.91% in 1975-2006. Additionally, the risk-adjusted performance measured by Sharpe-ratio improves too: it is 0.28 for the domestic stock and bond portfolio, and goes up to 0.31 when the portfolio includes GSCI. Also, the coefficient of correlation showed that the whole portfolio with a 10% GSCI is less risky than the pure stock and bond portfolio. However, it is remarkable that an increase in commodity proportion leads to more volatile returns in the whole portfolio. This fact can be explained by a high correlation of the GSCI with the energy sector. It is known as one of the most volatile commodity sectors. The correlation of the GSCI and crude oil in 1986-2006 was 73% with a coefficient of determination of 53%. It is also remarkable that an increase in commodity proportion of up to 40% leads to the effect that the strength of the relationship between the portfolio and the benchmark GSCI decreases substantially.

[111] Cf. Kaplan, P.D./ Lummer, S.L. (1997): p.14; Gorton, G./Rouwenhoorst , K.G. (2004): p. 15

The impact of including the DJ-AIG Commodity Index in a stock and bond portfolio is similar. At the domestic level, 10% DJ-AIGCI helps to reduce the standard deviation of the portfolio from 7.47% to 6.76%.

Generally, adding a small proportion of commodities to the portfolio results in improved performance, i.e. increasing returns and a decreasing standard deviation. Similar results hold for global stock and bond portfolios.

The next point of interest is the relationship strength between various commodity sectors. The following Exhibit 21 depicts the fact that correlations between commodity sectors are very low or negative for 2001-2006.

Exhibit 21: Correlations of the GSCI-Sub-Indices (2001-2006, monthly changes)

	GSCI Total Return	GS Agriculture Total Return	GS Energy Total Return	GS Industr. Metals Total Return	GS Livestock Total Return	GS Precious Metals Total Return
GSCI Total Return	1.0000	0.0647	0.9863	0.2778	-0.0031	0.2183
GS Agriculture TR	0.0647	1.0000	-0.0468	0.2177	0.0238	0.1530
GS Energy TR	0.9863	-0.0468	1.0000	0.1812	-0.0580	0.1825
GS Industrial Metals TR	0.2778	0.2177	0.1812	1.0000	-0.0470	0.3968
GS Livestock TR	-0.0031	0.0238	-0.0580	-0.0470	1.0000	-0.1271
GS Precious Metals TR	0.2183	0.1530	0.1825	0.3968	-0.1271	1.0000

Source: Bloomberg (data), own calculations

Remarkable and not surprising is the high correlation of the GSCI Energy index with the main index GSCI.

Of note is also the time-varying nature of returns and correlations between commodities. When constructing a commodity futures portfolio, the investor can potentially rely on the lack of correlation of a number of markets to dampen portfolio volatility. But if the investor is relying on diversification, then he must be careful on commodity correlation properties. Correlations amongst commodity markets can vary seasonally. At times seemingly unrelated markets can become temporarily highly correlated. This becomes problematic for portfolio diversification because two commodities that become unexpectedly correlated, can increase (or even double) the risk.

Normally, natural gas and corn prices are unrelated. But during the summer, they can be highly correlated. During a three-week period in July 1999, for example, natural gas and corn prices were with +85% highly correlated. Both corn and natural gas trades are heavily dependent on the weather in the US Midwest. And in July, 1999, the Midwest had very high temperatures. During that time, both corn and natural gas futures prices responded in a nearly identical fashion to weather forecasts and realisations.[112]

[112] Till, H. (2006): p. 6

Therefore, it is important to understand what the key factors are which drive a strategy's performance and to use short-term recent data in calculating correlations. If two trades have common drivers, then it can be assumed that their respective performances will be similar. Recent data can frequently capture the time-varying nature of correlations that long-term data average out. [113]

5.5 Added Value in μ-σ-Framework: Efficient Line and Efficient Portfolios

Efficient portfolios emerge if the possibility of risk reduction through diversification is exploited as far as it is possible and reasonable. Below the efficient frontier there are return-/risk-combinations, which are allowed but are inefficient because they have a lower return with the same risk compared to the portfolio on the efficient line. The so called minimum-variance-portfolio (MVP) stands at the beginning of the efficient curve and has the lowest risk in a whole set of efficient portfolios. [114]

An investor-specific optimal portfolio lies on the efficient line. The tangential point of the *risk indifference curve* and *efficient line* presents the optimal portfolio of the investor. The *selection* of an optimal portfolio is subjective and depends on the risk aversion of an investor. [115] The investor chooses the portfolio which promises the optimal utility for the investor, according to his risk attitude, from a whole set of efficient portfolios. [116] Thus, the investor will change the weightings of the single portfolio components as long as the portfolio features the desired return-risk-structure. The selection of an optimal structure of the portfolio and consequently the position of tangential portfolio on the efficient line, is dependent on the risk attitude of the investor. [117] The risk preference of the investor is presented by a *risk indifference curve* (cf. Exhibit 22).

---

[113] Cf. Till, H., Eagleeye, J. (2003): p. 22

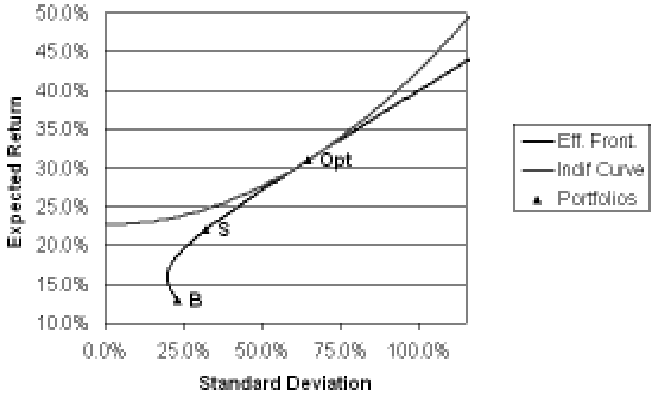
[114] Cf. Kleeberg, J.M. (1996): p. 587

[115] Cf. Breuer, W./Gürtler, M./Schuhmacher, F. (1999): pp. 40ff.; Garz, H./Günther, S./Moriabadi, C. (1997): p. 61

[116] The Utility function is determined as $U = \mu_P - \lambda \cdot \sigma_P^2$ with the risk aversion parameter Lambda which is calculated from benchmark portfolio $\lambda = \dfrac{\mu_{BM} - r_f}{2\sigma_{BM}^2}$.

[117] Cf. Garz, H./Günther, S./Moriabadi, C. (1997): p. 61

Exhibit 22: Efficient Frontier, Indifference Curve and Optimal Portfolio



Source: www.kent.kellogg.northwestern.edu

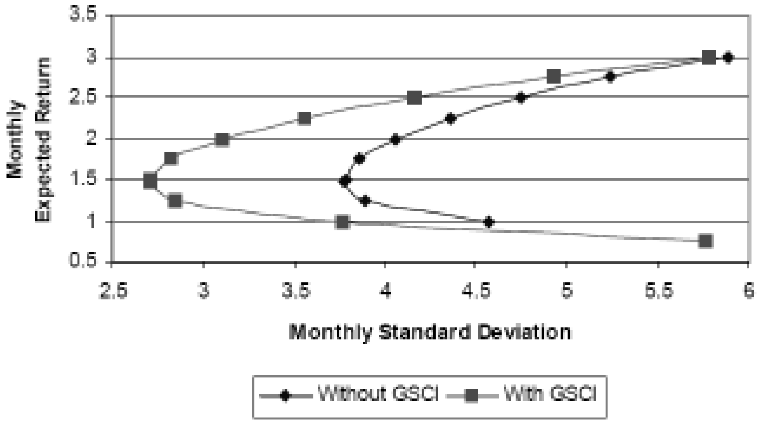
For each single risk preference there is an unique risk indifference curve. At each single point of the risk indifference curve the risk of the investor is the same. The portfolio theory takes into account individual return and risk preferences of the investor, provides as a result an optimal combination of investment alternatives and gives a clear activity recommendation for the investor.[118]

The common opinion nowadays is that commodities as a whole should be seen as a means of the portfolio diversification and a means of the risk-return-enhancement anyway.[119]

In 1994, two World Bank researchers Satyanarayan and Varangis noted that: "[…] the efficient frontier with commodity assets lies everywhere higher than the [international] portfolio without commodity assets, implying that for the same levels of return (risk), the portfolio with commodity assets provides lesser (higher) risk (return)."[120] The results of their research are presented in the Exhibit 23.

[118] Cf. Garz, H./Günther, S./Moriabadi, C. (1997): p. 18.
[119] Cf. Bodie, Z./Rosansky, V.I. (1980): pp. 27ff.; Jensen, G.R./ Johnson, R.R./ Mercer, J.M. (2002): pp. 100ff.
[120] Satyanarayan, S./Varangis, P. (1994): p. 19

Exhibit 23: Efficient Frontier for International Portfolios with and without the GSCI



Source: Satyanarayan, S./Varangis, P. (1994): p.19

The diversification benefits of commodities have also been studied by Ankrim and Hensel (1993), and Becker and Finnerty (2000). For instance, Becker and Finnerty established that the inclusion of long commodity futures contracts (CRB and GSCI) in portfolios improved the risk and return performance of stock and bond portfolios for the period of 1970 through 1990. They observed that the improvement is more pronounced for the 1970s than the 1980s due to the high inflation of the 1970s with commodities acting as an inflation hedge.[121]

The principal argument for investing in commodities is that investing in assets that rise in price parallel to inflation provides a natural hedge against losses in equity and debt holdings which typically lose value during periods of unexpected inflation. While previous studies have concentrated on measuring commodity returns during high and low inflation periods, the real benefits of commodity investment may lie in periods of unexpected rises in inflation. Anticipated inflation, which results in high bond yields and high equity earnings growth, may result in positive real returns for stocks and bonds. It is the unexpected inflation that should cause concern to every investor. In periods of unexpected inflation, market conditions may often lead to an increase in commodity prices, together with a weakness in stocks and bonds and thus provide a natural hedge against inflation.[122]

In the literature some authors differentiate between phases in the business cycle, and show that in a time of restrictive monetary policy commodities are actually able to provide portfolio return enhancement, whereas in a time of an expansive monetary policy it is more reasonable to “avoid” commodities and look for better investment alternatives.[123]

In 2002, Jensen, Mercer, and Johnson examined the diversification benefits of adding commodity futures to a traditional portfolio that consists of US equities, foreign equities, corporate bonds, and Treasury bills from 1973 through to 1999. Consistent with previous evidence,

[121] Cf. Becker, K./Finnerty, J. (2000): pp. 4ff.
[122] Cf. CISDM (2005): p. 11
[123] Cf. Jensen, G.R./ Johnson, R.R./ Mercer, J.M. (2000): pp. 489ff.

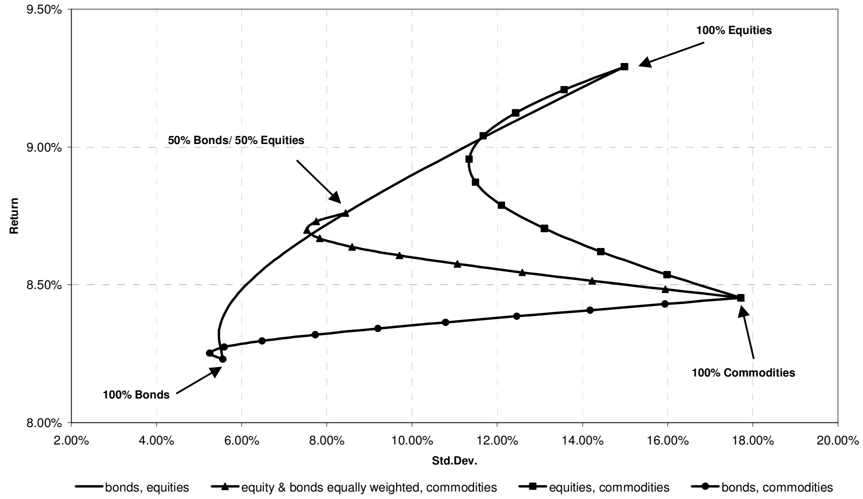
they found that commodity futures substantially enhance portfolio performance for investors and that managed futures provide the greatest benefit. They show that the benefits of adding commodity futures accrue almost exclusively when the Federal Reserve is following a restrictive monetary policy which is a consequence of the inflationary environment. The results also suggest that metals and agricultural futures contracts offer the biggest diversification benefits for investors. Overall, the findings indicate that investors should gauge monetary conditions to determine the optimal allocation of commodity futures within a portfolio, and whether a short or a long position should be established in a particular type of contract. [124]

The objective of this work is to investigate how commodities as a portfolio component behave regarding the risk-return-enhancement over various periods of time.

Building on the results of Section 5.3 the further analysis concentrates on the identification of profitable situations by adding commodities in a stock and bond portfolio, represented by the Standard & Poor's 500 and Lehman US Government Bond indices. All calculations are presented for the GSCI while the calculations for the DJ-AIGCI provide a similar picture.

In Exhibit 24 a set of efficient lines for the overall period from 1976 to May 2006 is presented.

Exhibit 24: Efficient Lines (1976-Mai 2006, monthly returns)



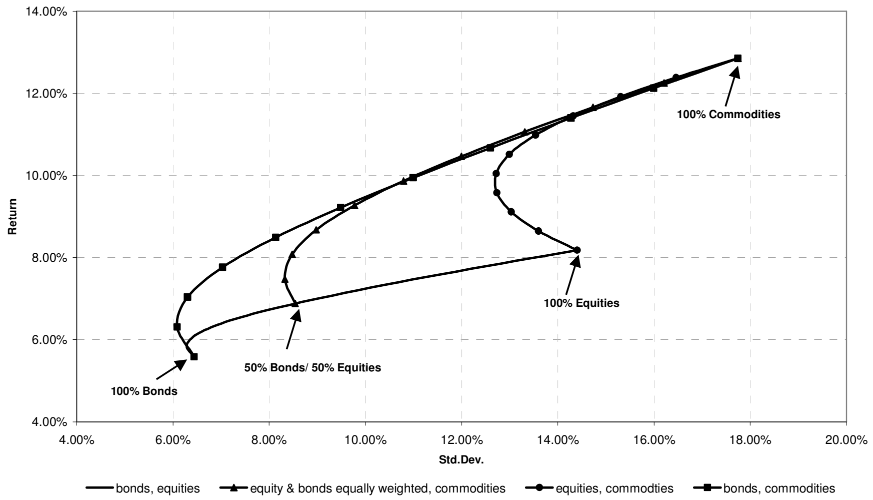
Source: own calculations

The picture reveals the fact that commodities did not really provide a better risk-return ratio over the whole period. In this case, only if the investor has a risk tolerance of above 12% the commodity addition to a pure equity portfolio would provide an insignificant risk-return-enhancement and cause only a small upwards shift of the efficient line.

The picture changes for the years 1976-1980, a **period of time with a high inflation** (cf. Exhibit 25).

[124] Cf. Jensen, G. R./Mercer, J. M./Johnson, R. R. (2002): pp. 100ff.

Exhibit 25: Efficient Lines (1976-1980, monthly returns)

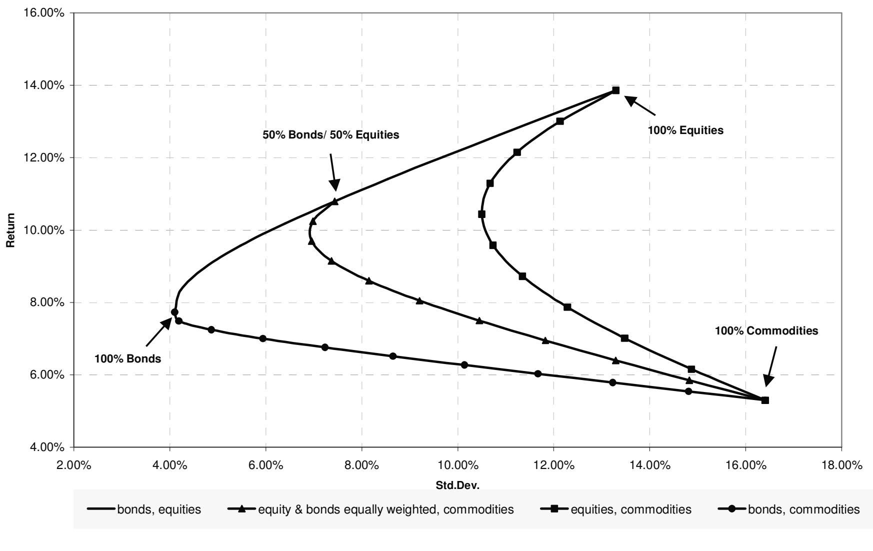


Source: own calculations

In these years including commodities in the portfolio was a profitable decision. It was a period in which commodity indices provided considerably better performance figures than the stock indices.

However, the picture for the years 1991 to 1999 in which **equity indices provided extraordinary returns** shows the exact opposite (cf. Exhibit 26).

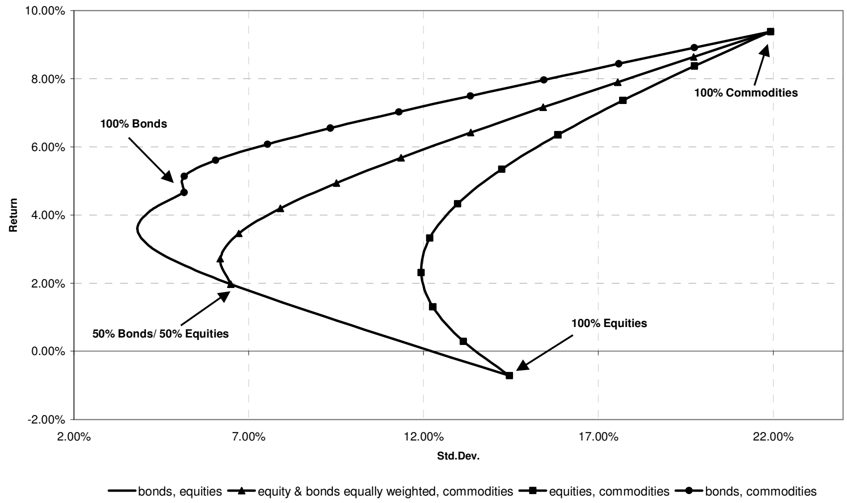
Exhibit 26: Efficient Lines (1991-1999, monthly returns)



Source: own calculations

The most impressive picture emerges for the years 2001 to 2006 with the **equity market slump** (cf. Exhibit 27).

Exhibit 27: Efficient Lines (2001-2006, monthly returns)



Source: own calculations

During that time a combination of commodities and bonds provided the best investment results while equities underperformed.

The empirical evidence on the statistical properties of commodity investments has confirmed the theoretically established positive effect of investing in commodities only in selected time periods. Nevertheless, it is obvious that it is not possible to issue a general recommendation that commodities should belong to the portfolio of each investor.

5.6 Criticism of Standard Deviation as Risk Measure

In the traditional and widely accepted mean-variance approach to portfolio management, a portfolio's investment risk is defined by its volatility of returns, measured by the standard deviation, or, equivalently, by the variance of the portfolio's return distribution. Using standard deviation as the measure of risk implies the understanding that both right and left deviations from the mean return are risky. Even the founder of the modern portfolio theory Harry Markowitz originally suggested a risk measure involving only negative outcomes (semi-variance), but rejected that approach in favour of standard deviation only in order to simplify the calculations.[125]

If investment returns are symmetrically distributed, particularly in the form of a normal distribution ("bell-shaped" curve), the chances of a positive outcome a certain distance away from the mean of the distribution are just as great as the chances of a negative outcome an equal distance in the opposite direction. But for not normally distributed investment returns standard deviation is an insufficient risk measure. For example, commodities can never lose their

[125] Cf. Markowitz, H. (1992): p. 194

real value. On the other hand, the potential upside gains on commodities are virtually unlimited. The commodities returns can be described by a **right-skewed** distribution rather than a normal distribution. In a right-skewed distribution there are more chances for an upside development than for a downside so that downside risk is limited. Consequently, standard deviation insufficiently characterises the risk of a right-skewed investment as it is ignoring the fact that most of the investment's volatility is on the "good" side of the investment's expected return.[126]

More complex downside risk measures with the only focus on the likelihood of undesirable investment results are provided by a family of statistics known as **Lower Partial Moments (LPM).** They can provide a better but also more complex solution for the portfolio optimisation problem.

6 Summary and Outlook

From the early 1990's to the present, the proposed role of commodities in traditional portfolios has changed depending on the macroeconomic and financial environment. Judging by historical results, this asset class can provide attractive absolute and relative returns in the appropriate macroeconomic environments. But like indexed equity investments, due care must be exercised in deciding when and how much to allocate. For example, investing in commodities in 1998 was unlucky because the GSCI was in deep contango at that time. This example emphasizes that the risks in commodity investments are similar to the risks in equity market investments, especially in the case of an investment in commodities when they are in surplus or in unfavourable macroeconomic environments.

Direct commodity investment or investments in commodity futures can provide significant portfolio diversification benefits beyond those achievable from commodity-based stock and bond investment. These benefits stem from the unique relationship of commodities to market forces such as unexpected inflation.

The objective of this work was to explain the investment possibilities in the commodity markets, and to examine whether commodities as an asset class are able to contribute to enhance of the risk-return-ratio of a portfolio.

As a result of this empirical study a note can be made that commodities as an asset class provided such enhancement only in select periods of time, for example periods with an inflationary environment and restrictive monetary policy. The statement that commodities have outperformed other investment options in the past is a wholesale one and highly dependent on the time period analysed.

[126] A simple mathematical transformation can often convert a right-skewed distribution to a normal (or rather "lognormal) distribution but there is no empirical evidence that such lognormal distribution adequately characterizes investment returns.

Adding a commodity component to a diversified portfolio of assets was based on the Portfolio Selection Models and resulted in an enhanced risk-adjusted performance in many cases. But the application of passive investment strategies with commodities is relatively difficult as the input factors such as expected return and risk measure (standard deviation or other) can only be estimated from historical data and can not be simply extrapolated into the future because the commodity returns development is subject to numerous factors both on the supply and demand side.

From the macro-economic point of view the point in time to invest in commodities is in phases with a high expected and unexpected inflation rate.

Besides that, the time to invest in commodities is during times of low inventories and when their futures curves are in backwardation.[127]

Taking into consideration the current effects of all essential factors such as the continued growth of the global economy, a persistent demand for commodities from Asia, China, etc., the US dollar depreciation and resulting rising interest rates during the last months in the USA as well as in the EU, the strengthening of the monetary policy, a rising government budget deficit, the energy shortage and business cycle phases, it can be assumed that commodities can offer benefit opportunities for the next years.

In recent years, investable commodity indices and commodity linked assets have increased the number of available commodity-based products. For the next years two further developments in the commodity market are expected. First, there will be an improvement of the future contracts liquidity because of their increasing usage among producers forced to hedge their products against commodity price changes. Second, a growing popularity of commodities amongst institutional asset managers, because of excess capital which has to be invested.

[127] It is valid for the long-only strategy, typical for most commodity funds.

REFERENCES

Ankrim, E. M./Hensel, C. R. (1993): Commodities in Asset Allocation: A Real-Asset Alternative to Real Estate?; in: Financial Analysts Journal, Vol. 49, Issue 3, May/June 1993, pp.20-29

Atonce Capital Management, online; Available: http://www.atonce.ch/ACM/news/news0326

Auckenthaler, C. (1994): Theorie und Praxis des modernen Portfolio-Managements, 2., vollständig überarbeitete und ergänzte Auflage, Bern u.a., 1994, zugl. Diss., Univ., Zürich, 1991

Becker, K./Finnerty, J. (2000): Indexed Commodity Futures and the Risk and Return of Institutional Portfolios, Office of Futures and Options Research, Working Paper, 2000

Biermann, B./Grosser, K. (1999): Lexikon Finanzmathematik, Statistik, Stuttgart, 1999

Bodie, Z., Rosansky, V.I. (1980): Risk and Return in Commodity Futures; in: Financial Analysts Journal, Vol.36, May/June 1980, pp. 3-14

Bohley, P. (1996): Statistik: einführendes Lehrbuch für Wirtschafts- und Sozialwissenschaftler, 6th edition, München, Wien, 1996

Breuer, W./Gürtler, M./Schuhmacher, F. (1999): Portfolio-Management: theoretische Grundlagen und praktische Anwendungen, Wiesbaden, 1999

Brown, S.P. (2006): The Commodity Question: can adding commodities to a portfolio improve performance?; in: CFA Magazine, January/February 2006, pp. 44-45

Carter, C.A./Rausser, G.C./Schmitz, A. (1983): Efficient Asset Portfolios and the Theory of Normal Backwardation; in: The Journal of Political Economy, Vol. 91, No. 2, April 1983, pp. 319-331

CISDM (2005): The Benefits of Commodity Investment, 2005 Update, Center for International Securities and Derivatives Markets (CISDM), June 2005; Download: cisdm.som.umass.edu/research/pdffiles/benefitsofcommodities.pdf

CME (2005): An Introduction to CME Commodity Products; Download: http://www.cme.com/edu/co/onres/cobrchrs15544.html

Elton, E.J., Gruber, M.J. (1995): Modern portfolio theory and investment analysis, 5th edition, New York, 1995

Erb, C.B./Harvey, C.R. (2005): The Tactical and Strategic Value of Commodity Futures; NBER Working Paper 11222; Download: faculty.fuqua.duke.edu/~charvey/ Research/Working_Papers/W77_The_tactical_and.pdf

Erb, C.B./Harvey, C.R. (2006): The Strategic and Tactical Value of Commodity Futures; in: Financial Analysts Journal, Vol. 62, Issue 2, March/April 2006, pp. 69-97

Fama, E. F./French, K. R.(1987): Commodity Future Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage; in: Journal of Business, Vol. 60, Issue 1, January 1987, pp.55-73

Fama, E. F./French, K. H. (1988): Business Cycles and the Behavior of Metals Prices; in: The Journal of Finance, Vol. 43, Issue 5, December 1988, pp.1075-1093

Garz, H./Günther, S./Moriabadi, C. (1997): Portfolio-Management: Theorie und Anwendung, Frankfurt am Main, 1997

GFMS (2005): World Silver Survey 2005, GFMS Limited on behalf of the Silver Institute; Download: www.silverinstitute.org

Goldman Sachs (2006): The GSCI Manual: A Guide to the Goldman Sachs Commodity Index - 2006 Edition; Download: www.gs.com/gsci/docs/GSCI_Manual_2006_FINAL.pdf

Gorton, G./Rouwenhoorst , K.G. (2004): Facts and fantasies about commodity futures, Yale ICF Working Paper No.04-20, February 2005; Download: http://ssrn.com/ abstract =560042

Greer, R.J. (2000): The Nature of Commodity Index Returns; In: The Journal of Alternative Investments, Summer 2004, pp.45-53

Greer, R. J. (2005): Commodity Indexes for Real Return & Efficient Diversification; In: An Investor Guide to Commodities, Deutsche Bank, April 2005, pp.24-34

Hielscher, U. (1999): Investmentanalyse, 3rd edition, München, 1999

Hull, J.C. (2003): Options, Futures and Other Derivatives, New Jersey, 2003

Idzorek, T.M. (2006): Strategic Asset Allocation and Commodities, Ibbotson, March 2006; Download: http://www.ibbotson.com/content/kc_published_research_search.asp?catalog=Article&category=Asset%20Allocation&prodID=ARTC4420061

Jensen, G.R./Johnson, R.R./Mercer, J.M. (2000): Efficient Use of Commodity Futures in Diversified Portfolios; in: The Journal of Futures Markets, Vol. 20, Issue 5, 2002, pp.489-506

Jensen, G.R./Johnson, R.R./Mercer, J.M. (2002): Tactical Asset Allocation and Commodity Futures; in: Journal of Portfolio Management, Vol. 28, Issue 4, Summer 2002, pp.100-111

Kaplan, P.D./Lummer, S. L. (1997): GSCI Collateralised Futures as a Hedging and Diversification Tool for Institutional Investors: an Update; In: Journal of Investing, vol. 7, no. 4 (Winter) 1997, pp.11-17

Kaplan, P.D. (1998): Asset Allocation Models Using the Markowitz Approach, January 1998; Download: www.misp.it/doc/materiali_doc/Curti1-EN.pdf

Kavalis, N. (2006): Commodity Prices and the Influence of the US Dollar, GFMS Limited on behalf of the World Gold Council, January 2006 Download: http://www.gold.org/value/ stats/ research/index.html

Keynes, J.M. (1934): A Treatise on Money, London, 1934

Kleeberg, J.M. (1995): Der Anlageerfolg des Minimum-Varianz-Portfolios: eine empirische Untersuchung am deutschen, kanadischen, und US-amerikanischen Aktienmarkt, Bad Soden/Ts., 1995, zugl. Diss., Univ., Münster, 1994

Kleeberg, J.M. (1996): Rendite und Risiko des Minimum-Varianz-Portfolios; in: Österreichisches Bankarchiv (ÖBA), Vol.44, issue 8 1996, pp.587-594

Kolb, R.W. (1992): Is Normal Backwardation Normal?; In: Journal of Futures Markets 12, pp.75–91

Kolb, R. (1996): The Systematic Risk of Futures Contracts; in: The Journal of Futures Markets, Vol.16, No. 6 (1996), pp. 631–654

Lange, K. (1996): Statistik Formelsammlung, 3rd edition, Zwickau, 1996

Lautier, D. (2005): Term Structure Models of Commodity Prices: A Review; in: Journal of Alternative Investments, Vol. 8, Issue 1, Summer2005, pp. 42-64

Lewis, M. (2005): Convenience Yields, Term Structures & Volatility Across Commodity Markets; In: An Investor Guide to Commodities, Deutsche Bank, April 2005, pp.18-23

Lister, M. (1997): Risikoadjustierte Ergebnismessung und Risikokapitalallokation, Frankfurt/Main, 1997

Litzenberger, R.H./Rabinowitz, N. (1995): Backwardation in Oil Futures Markets: Theory and Empirical Evidence; in: The Journal of Finance, Vol. 50, Issue 5, December 1995, pp.1517-1545

Lummer, S. L./Siegel, L.B. (1993): GSCI Collateralised Futures: A Hedging and Diversification Tool for Institutional Investors; In: Journal of Investing, Summer 1993, pp.75-82

Markowitz, H.M. (1952): Portfolio Selection; in: Journal of Finance, 7.Vol., No. 1, March 1952, pp.77-91

Markowitz, H.M. (1992): Portfolio Selection, Efficient Diversification of Investments, 2nd Edition, Cambridge, 1992

Mezger,M./Eibl, C. (2005): Rohstoffe im Portfoliomanagement: Die (fast) vergessene Anlageklasse; In: Die Bank, issue 06/2005, pp.8-14

Mezger,M./Eibl, C. (2006): Portfoliomanagement: Gewinne mit Rohstoffen; In: Die Bank, issue 07/2006, pp.20-26

Moncur, G. (2005): Indices enticing Investors, September 2005; Download: http://www.gold.org/value/stats/research/index.html

Moncur, G./Kettle, P. (2005): Metals and Backwardation, September 2005; Download: http://www.gold.org/value/stats/research/index.html

Neubauer, W. (1994): Statistische Methoden: ausgewählte Kapitel für Wirtschaftswissenschaftler, München, 1994

Oberhofer, G. (2001): Hedge Funds – a new Asset Class or just a Change in Perspective?; In: Alternative Investment Management Association (AIMA) Newsletter, December 2001; Download: http://www.aima.org/uploads/2001/Dec/frankrussell.pdf

Oehler, A./Unser, M. (2002): Finanzwirtschaftliches Risikomanagement, Berlin u.a., 2002

Perridon, L./Steiner, M. (2002): Finanzwirtschaft der Unternehmung, 11th edition, München, 2002

Poddig, T./Brinkmann, U./Seiler, K. (2005): Portfolio Management: Konzepte und Strategien, Bad Soden/Ts., 2005

Pulvermacher, K. (2005a): What are Commodities?, March 2005; Download: http://www.gold.org/value/stats/research/index.html

Pulvermacher, K. (2005b): Commodity Returns and the Economic Cycle, Mai 2005; Download: http://www.gold.org/value/stats/research/index.html

Radetzki, M. (1990): A Guide to Primary Commodities in the World Economy, Oxford, 1990

Rehkugler, H. (2002): Grundlagen des Portfoliomanagements; in: Kleeberg, J.M./ Rehkugler, H. [Hrsg.]: Handbuch Portfoliomanagement, 2nd edition, Bad Soden /Ts., 2002, pp.3-41

Rudolph, B. (1995): Theoretische Ansätze und Umsetzung der Anlageplanung; in: Cramer, J.-E./Rudolph, B. [Hrsg.]: Handbuch für Anlageberatung und Vermögensverwaltung: Methoden und Instrumente des Portfoliomanagements, Frankfurt am Main, 1995, pp. 25-44

Satyanarayan, S./Varangis, P. (1994): An Efficient Frontier for International Portfolios with Commodity Assets, Policy Research Working Paper 1266, The World Bank, March 1994; Download: www-wds.worldbank.org/.../WDSP/IB/1994/03/01/000009265_3961006020009/ Rendered/PDF/multi_page.pdf

Schneeweis, T./Spurgin, R. (1997): Energy Based Investment Products and Investor Asset Allocation, Center for International Securities and Derivatives Markets (CISDM), Isenberg School of Management, University of Massachusetts, 1997

Sharpe, W.F./Alexander, G.J./ Bailey, J.V. (1995): Investments, 5th edition, New York, 1995

Singer, B. D./Staub, R./Terhaar, K. (2002): Determining the Appropriate Allocation to Alternative Investments; in: Hedge Fund Management, CFA Institute, 2002, pp.4-15

Steiner, M./Bruns, C. (2002): Wertpapiermanagement: Professionelle Wertpapieranalyse und Portfoliostrukturierung, 8th edition, 2002, Stuttgart

Steiner, P./Uhlir, H. (2001): Wertpapieranalyse, 4th edition, Heidelberg, 2001

Till, H. (2000a): Passive Strategies in the Commodity Futures Markets; In: Derivatives Quarterly, Fall 2000, pp. 49-54

Till, H.(2000b): Systematic Returns in Commodity Futures, In: Commodities Now, September 2000, pp. 75-79

Till, H. (2003): Actively Timing an Investment in the Goldman Sachs Commodity Index, April 2003; Download: http://www.premiacap.com/publications.php

Till, H.(2006): Portfolio Risk Measurement in Commodity Futures Investments, 2006; Download: http://www.premiacap.com/publications.php

Till, H./Eagleeye, J. (2003): The Risks of Commodity Investing, Mai 2003; Download: http://www.premiacap.com/publications.php

Till,H./Eagleeye, J. (2005): Commodities: Active Strategies for Enhanced Return; in: Journal of Wealth Management, Vol.8, No.2 (Fall 2005), pp.42-61

Vrugt, E. B. (2003): Tactical Commodity Strategies in Reality: An Economic Theory Approach, ABP Working Paper, 2003; Download: http://www.fdewb.unimaas.nl/finance/workingpapers

Weiser, S. (2003): The Strategic Case for Commodities in Portfolio Diversification; In: Commodities Now, 2003, pp. 7-11

Online-Sources:

Commodities Research Unit (CRU): http://www.crugroup.com/

Copper Development Association: www.copper.org

Copper Development Association UK: www.cda.org.uk

Dow Jones Indexes: http://djindexes.com/mdsidx/index.cfm?event=showAigAbout

European Aluminium Association: www.aluminium.org

International Aluminium Institute: www.world-aluminium.org

International Stainless Steel Forum: www.worldstainless.org

The Silver Institute: www.silverinstitute.org

World Gold Council: www.gold.org

World Bureau of Metal Statistics: www.world-bureau.org

FRANKFURT SCHOOL / HFB – WORKING PAPER SERIES

No.	Author/Title	Year
80.	Cremers, Heinz / Walzner, Jens Risikosteuerung mit Kreditderivaten unter besonderer Berücksichtigung von Credit Default Swaps	2007
79.	Cremers, Heinz / Traughber, Patrick Handlungsalternativen einer Genossenschaftsbank im Investmentprozess unter Berücksichtigung der Risikotragfähig-keit	2007
78.	Gerdesmeier, Dieter / Roffia, Barbara Monetary Analysis: A VAR Perspective	2007
77.	Heidorn, Thomas / Kaiser, Dieter G. / Muschiol, Andrea Portfoliooptimierung mit Hedgefonds unter Berücksichtigung höherer Momente der Verteilung	2007
76.	Schalast, Christoph / Ockens, Klaas / Jobe, Clemens J. / Safran, Robert Work-Out und Servicing von notleidenden Krediten – Berichte und Referate des HfB-NPL Servicing Forums 2006	2006
75.	Abrar, Kamyar Fusionskontrolle in dynamischen Netzsektoren am Beispiel des Breitbandkabelsektors	2006
74.	Schanz, Kai-Michael / Schalast, Christoph Wertpapierprospekte – Markteinführungspublizität nach EU-Prospektverordnung und Wertpapierprospektgesetz 2005	2006
73.	Dickler, Robert A. / Schalast, Christoph Distressed Debt in Germany: What´s Next? Possible Innovative Exit Strategies	2006
72.	Belke, Ansgar / Polleit, Thorsten How the ECB and the US Fed set interest rates	2006
71.	Heidorn, Thomas / Hoppe, Christian / Kaiser, Dieter G. Heterogenität von Hedgefondsindizes	2006
70.	Löchel, Horst / Baumann, Stefan The Endogeneity Approach of the Theory of Optimum Currency Areas - What does it mean for ASEAN + 3?	2006
69.	Heidorn, Thomas / Trautmann, Alexandra Niederschlagsderivate	2005
68.	Heidorn, Thomas / Hoppe, Christian / Kaiser, Dieter G. Möglichkeiten der Strukturierung von Hedgefondsportfolios	2005
67.	Weber, Christoph Kapitalerhaltung bei Anwendung der erfolgsneutralen Stichtagskursmethode zur Währungsumrechnung	2005
66.	Schalast, Christoph / Daynes, Christian Distressed Debt-Investing in Deutschland - Geschäftsmodelle und Perspektiven -	2005
65.	Gerdesmeier, Dieter / Polleit, Thorsten Measures of excess liquidity	2005
64.	Hölscher, Luise / Harding, Perham / Becker, Gernot M. Financing the Embedded Value of Life Insurance Portfolios	2005
63.	Schalast, Christoph Modernisierung der Wasserwirtschaft im Spannungsfeld von Umweltschutz und Wettbewerb – Braucht Deutschland eine Rechtsgrundlage für die Vergabe von Wasserversorgungskonzessionen? –	2005
62.	Bayer, Marcus / Cremers, Heinz / Kluß, Norbert Wertsicherungsstrategien für das Asset Management	2005
61.	Löchel, Horst / Polleit, Thorsten A case for money in the ECB monetary policy strategy	2005
60.	Schanz, Kay-Michael / Richard, Jörg / Schalast, Christoph Unternehmen im Prime Standard - „Staying Public“ oder „Going Private“? - Nutzenanalyse der Börsennotiz -	2004
59.	Heun, Michael / Schlink, Torsten Early Warning Systems of Financial Crises - Implementation of a currency crisis model for Uganda	2004
58.	Heimer, Thomas / Köhler, Thomas Auswirkungen des Basel II Akkords auf österreichische KMU	2004
57.	Heidorn, Thomas / Meyer, Bernd / Pietrowiak, Alexander Performanceeffekte nach Directors´Dealings in Deutschland, Italien und den Niederlanden	2004

56. Gerdesmeier, Dieter / Roffia, Barbara
The Relevance of real-time data in estimating reaction functions for the euro area 2004

55. Barthel, Erich / Gierig, Rauno / Kühn, Ilmhart-Wolfram
Unterschiedliche Ansätze zur Messung des Humankapitals 2004

54. Anders, Dietmar / Binder, Andreas / Hesdahl, Ralf / Schalast, Christoph / Thöne, Thomas
Aktuelle Rechtsfragen des Bank- und Kapitalmarktrechts I :
Non-Performing-Loans / Faule Kredite - Handel, Work-Out, Outsourcing und Securitisation 2004

53. Polleit, Thorsten
The Slowdown in German Bank Lending – Revisited 2004

52. Heidorn, Thomas / Siragusano, Tindaro
Die Anwendbarkeit der Behavioral Finance im Devisenmarkt 2004

51. Schütze, Daniel / Schalast, Christoph (Hrsg.)
Wider die Verschleuderung von Unternehmen durch Pfandversteigerung 2004

50. Gerhold, Mirko / Heidorn, Thomas
Investitionen und Emissionen von Convertible Bonds (Wandelanleihen) 2004

49. Chevalier, Pierre / Heidorn, Thomas / Krieger, Christian
Temperaturderivate zur strategischen Absicherung von Beschaffungs- und Absatzrisiken 2003

48. Becker, Gernot M. / Seeger, Norbert
Internationale Cash Flow-Rechnungen aus Eigner- und Gläubigersicht 2003

47. Boenkost, Wolfram / Schmidt, Wolfgang M.
Notes on convexity and quanto adjustments for interest rates and related options 2003

46. Hess, Dieter
Determinants of the relative price impact of unanticipated Information in 2003
U.S. macroeconomic releases

45. Cremers, Heinz / Kluß, Norbert / König, Markus
Incentive Fees. Erfolgsabhängige Vergütungsmodelle deutscher Publikumsfonds 2003

44. Heidorn, Thomas / König, Lars
Investitionen in Collateralized Debt Obligations 2003

43. Kahlert, Holger / Seeger, Norbert
Bilanzierung von Unternehmenszusammenschlüssen nach US-GAAP 2003

42. Beiträge von Studierenden des Studiengangs BBA 012 unter Begleitung von Prof. Dr. Norbert Seeger
Rechnungslegung im Umbruch - HGB-Bilanzierung im Wettbewerb mit den internationalen 2003
Standards nach IAS und US-GAAP

41. Overbeck, Ludger / Schmidt, Wolfgang
Modeling Default Dependence with Threshold Models 2003

40. Balthasar, Daniel / Cremers, Heinz / Schmidt, Michael
Portfoliooptimierung mit Hedge Fonds unter besonderer Berücksichtigung der Risikokomponente 2002

39. Heidorn, Thomas / Kantwill, Jens
Eine empirische Analyse der Spreadunterschiede von Festsatzanleihen zu Floatern im Euroraum
und deren Zusammenhang zum Preis eines Credit Default Swaps 2002

38. Böttcher, Henner / Seeger, Norbert
Bilanzierung von Finanzderivaten nach HGB, EstG, IAS und US-GAAP 2003

37. Moormann, Jürgen
Terminologie und Glossar der Bankinformatik 2002

36. Heidorn, Thomas
Bewertung von Kreditprodukten und Credit Default Swaps 2001

35. Heidorn, Thomas / Weier, Sven
Einführung in die fundamentale Aktienanalyse 2001

34. Seeger, Norbert
International Accounting Standards (IAS) 2001

33. Stehling, Frank / Moormann, Jürgen
Strategic Positioning of E-Commerce Business Models in the Portfolio of Corporate Banking 2001

32. Strohhecker, Jürgen / Sokolovsky, Zbynek
Fit für den Euro, Simulationsbasierte Euro-Maßnahmenplanung für Dresdner-Bank-Geschäftsstellen 2001

31.	Roßbach, Peter Behavioral Finance - Eine Alternative zur vorherrschenden Kapitalmarkttheorie?	2001
30.	Heidorn, Thomas / Jaster, Oliver / Willeitner, Ulrich Event Risk Covenants	2001
29.	Biswas, Rita / Löchel, Horst Recent Trends in U.S. and German Banking: Convergence or Divergence?	2001
28.	Löchel, Horst / Eberle, Günter Georg Die Auswirkungen des Übergangs zum Kapitaldeckungsverfahren in der Rentenversicherung auf die Kapitalmärkte	2001
27.	Heidorn, Thomas / Klein, Hans-Dieter / Siebrecht, Frank Economic Value Added zur Prognose der Performance europäischer Aktien	2000
26.	Cremers, Heinz Konvergenz der binomialen Optionspreismodelle gegen das Modell von Black/Scholes/Merton	2000
25.	Löchel, Horst Die ökonomischen Dimensionen der ‚New Economy‘	2000
24.	Moormann, Jürgen / Frank, Axel Grenzen des Outsourcing: Eine Exploration am Beispiel von Direktbanken	2000
23.	Heidorn, Thomas / Schmidt, Peter / Seiler, Stefan Neue Möglichkeiten durch die Namensaktie	2000
22.	Böger, Andreas / Heidorn, Thomas / Graf Waldstein, Philipp Hybrides Kernkapital für Kreditinstitute	2000
21.	Heidorn, Thomas Entscheidungsorientierte Mindestmargenkalkulation	2000
20.	Wolf, Birgit Die Eigenmittelkonzeption des § 10 KWG	2000
19.	Thiele, Dirk / Cremers, Heinz / Robé, Sophie Beta als Risikomaß - Eine Untersuchung am europäischen Aktienmarkt	2000
18.	Cremers, Heinz Optionspreisbestimmung	1999
17.	Cremers, Heinz Value at Risk-Konzepte für Marktrisiken	1999
16.	Chevalier, Pierre / Heidorn, Thomas / Rütze, Merle Gründung einer deutschen Strombörse für Elektrizitätsderivate	1999
15.	Deister, Daniel / Ehrlicher, Sven / Heidorn, Thomas CatBonds	1999
14.	Jochum, Eduard Hoshin Kanri / Management by Policy (MbP)	1999
13.	Heidorn, Thomas Kreditderivate	1999
12.	Heidorn, Thomas Kreditrisiko (CreditMetrics)	1999
11.	Moormann, Jürgen Terminologie und Glossar der Bankinformatik	1999
10.	Löchel, Horst The EMU and the Theory of Optimum Currency Areas	1998
09.	Löchel, Horst Die Geldpolitik im Währungsraum des Euro	1998
08.	Heidorn, Thomas / Hund, Jürgen Die Umstellung auf die Stückaktie für deutsche Aktiengesellschaften	1998
07.	Moormann, Jürgen Stand und Perspektiven der Informationsverarbeitung in Banken	1998
06.	Heidorn, Thomas / Schmidt, Wolfgang LIBOR in Arrears	1998
05.	Jahresbericht 1997	1998

04.	Ecker, Thomas / Moormann, Jürgen Die Bank als Betreiberin einer elektronischen Shopping-Mall	1997
03.	Jahresbericht 1996	1997
02.	Cremers, Heinz / Schwarz, Willi Interpolation of Discount Factors	1996
01.	Moormann, Jürgen Lean Reporting und Führungsinformationssysteme bei deutschen Finanzdienstleistern	1995

FRANKFURT SCHOOL / HFB – WORKING PAPER SERIES
CENTRE FOR PRACTICAL QUANTITATIVE FINANCE

No.	Author/Title	Year
05.	Griebsch, Susanne/ Kühn, Christoph / Wystup, Uwe Instalment Options: A Closed-Form Solution and the Limiting Case	2007
04.	Boenkost, Wolfram / Schmidt, Wolfgang M. Interest Rate Convexity and the Volatility Smile	2006
03.	Becker, Christoph/ Wystup, Uwe On the Cost of Delayed Currency Fixing	2005
02.	Boenkost, Wolfram / Schmidt, Wolfgang M. Cross currency swap valuation	2004
01.	Wallner, Christian / Wystup, Uwe Efficient Computation of Option Price Sensitivities for Options of American Style	2004

HFB – SONDERARBEITSBERICHTE DER HFB - BUSINESS SCHOOL OF FINANCE & MANAGEMENT

No.	Author/Title	Year
01.	Nicole Kahmer / Jürgen Moormann Studie zur Ausrichtung von Banken an Kundenprozessen am Beispiel des Internet (Preis: € 120,--)	2003

Printed edition: € 25.00 + € 2.50 shipping

Download: http://www.frankfurt-school.de/content/de/research/Publications/list_of_publication

Order address / contact

Frankfurt School of Finance & Management
Sonnemannstr. 9 – 11 ▪ D – 60314 Frankfurt/M. ▪ Germany
Phone: +49 (0) 69 154 008 – 734 ▪ Fax: +49 (0) 69 154 008 – 728
eMail: m.biemer@frankfurt-school.de
Further information about Frankfurt School of Finance & Management
may be obtained at: http://www.frankfurt-school.de