LUND UNIVERSITY
School of Economics and Management

What to own when it all crashes

- Optimal risk-adjusted portfolios during financial distress

Department of Economics

Master essay 1 – NEKN01

Master's Programme in Economics

Essay seminar: 2018-08-28

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Abstract

This paper examines which asset classes that has given the highest risk-adjusted returns during the period of 1914-2013, with a focus on financial crises. The portfolios have been produced by calculation and optimization of the Sharpe ratio as a measure of risk-adjusted returns. The analysis included Sweden, the U.S and Japan and consisted of 9 different asset classes: global stocks, domestic stocks, short- and long-term domestic interest rates, oil, gold, silver, commodities and domestic housing. The results showed that in 13 out of 15 optimal risk-adjusted portfolios during financial distress, fixed-income securities were the most efficient asset. The paper also focuses on the fact that we are experiencing historically low interest rates which might affect future optimal risk-adjusted portfolios. The Bank of Japan lowered their rates in the late 1990s, and the portfolio that were computed during this period, consisted to 2/3 of global and domestic stocks together with oil and silver. Alternative portfolios for Sweden and the U.S during the crash of 2006-2009 was also computed, where fixed-income securities were removed. The result was a weight of 68 per cent given to Swedish housing and 32 per cent given to gold in the Swedish portfolio, and 82 per cent given to gold and 17 per cent given to global stocks in the U.S portfolio. This last result might indicate that gold is the safe haven, which it often is seen as.

Keywords: risk-adjusted returns, financial crash, Sharpe ratio, interest rates, safe haven

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1. Introduction

The history tells us that every 7-9 years we have some sort of financial crisis. If this is true for the future, we are well over due this time since the large crisis in 2007-2009, which is considered the largest crash since the Great Depression in 1930s. Today, the central banks are fishing in muddy water with their negative rates and we have a more complicated structure of different asset classes than ever before. Are these reasons to think that we have the worst crash ever ahead of us?

My main thought with this thesis was to see if I could find an optimal asset or optimal portfolio that seems to overperform in times when stocks are plummeting. Different crashes derive from different sectors, for example the housing market in 2007/2008, the stock market in the Dot-com bubble 2001 and sovereign debt in the 1998 Russian financial crisis. It would be reasonable to assume that the optimal portfolio would be some sort of hedge against the triggering factor which then would mean that there is no optimal crash portfolio over time. I will look at the beta values of assets, in other words, the correlation with the stock market, over time and in different time periods to try to find out which assets tend to correlate with the stock market during crashes.

The question that I want to answer is:

Is there any asset or portfolio that give higher risk-adjusted returns during several periods of financial distress?

To address the questions, I will compute returns, betas and optimal portfolios for nine different types of assets with data from 15 different countries and four different commodities between the years of 1914 to 2013. The focus will lie on a global perspective, together with in-depth review of three different countries, namely USA, Japan and Sweden. The optimal portfolios will be re-weighted every four years. The reason for this is to capture different financial crises and try to find similarities and differences between different periods.

The remainder of this thesis is structured as follows. In section 2, I will explain the theoretical background for portfolio selection and capital asset market pricing together with the formulas for the calculations used. The second part of section 2 will include a review of the earlier

research that are done on long-term returns and asset correlation and returns during financial crises.

Section 3 will describe the scientific method that permeate the approach used in the paper. The second part of section 3 describes the empirical method of data collection and limitations used to reach conclusions and results.

Section 4 is a combination of the results and conclusion drawn from the data. Returns and optimized portfolios will be displayed together with an attempt to find patterns in different periods and different geographical areas.

The last section of the thesis, section 5, includes the end discussion. This is a summary of the rest of the thesis, together with a review of the earlier research done in similar areas.

2. Theory

2.1 Portfolio selection and Mean-Variance

In *Portfolio selection* (1952), Harry Markowitz described the relationship between asset returns, variance and covariance of assets in a certain investment portfolio. According to Markowitz, all investors makes a trade-off between risk and returns in a Pareto-optimal combination (Markowitz, 1990). This lead to the creation of the so-called *efficient frontier* which gives optimal combinations of assets based on the relationship between risk and return. Assets that are not found on the efficient frontier, are therefore *inefficient* since they do not give the optimal return at the given risk level. With either a given requirement of return, or risk, an investor can use the efficient frontier to choose weights to different assets in a portfolio (Markowitz, p. 81–84, 1952).

Simplified, it could be said that Markowitz in *Portfolio selection* states that portfolio selection should be done with respect to mean and variance (Markowitz, p. 91, 1952). The foundation of portfolio selection, however, is diversification of assets which spreads risk and return, and is preferred to non-diversified portfolios (Markowitz, p. 77, 1952)

2.2 CAPM

Presented in articles by William Sharpe (1964), John Lintner (1965) and Jan Mossin (1966), The Capital Asset Pricing Model (hereafter referred to as CAPM) comprises several assumptions regarding expected return on risky assets. Like in Markowitzs *Portfolio Selection*, investors are assumed to optimize their portfolios given risk and expected return. The implication of this theory is that all investors should hold the same portfolio, namely the market portfolio which includes all assets in the economy with weights given by the tangent Capital Allocation Line (CAL) on the efficient frontier (Bodie et al., 2014, p. 291-292).

2.3 Expected return and Beta

According to CAPM, the expected return of an asset can be stated as:

$$E(r) = r_f + beta[E(r_M) - r_f]$$

Where:

$$E(r) = Expected\ return$$
$$r_f = risk\ free\ rate$$
$$E(r_M) = Expected\ market\ return$$
$$beta = \frac{cov(r_i, r_m)}{var(r_m)}$$

Beta is a measure of how much the individual asset contributes to the variance of the market portfolio in proportion to the market portfolio's total variance.

If a portfolio is the weighted average of all available assets, the portfolio's beta will be 1, since that would be equal to the market portfolio. On the other hand, a beta over 1 is seen as "aggressive" and a beta below 1 as "defensive". The former implies a high sensitivity to market swings, while the former entails a lower than average sensitivity to market swings (Bodie et al., 2014, p. 297). Another way of stating what beta is, is as a measure of the systematic risk where an asset with beta 1 falls and rises with the same percentage as the market portfolio (Harvard Business Review, 1982).

2.4 SML

The Security Market Line, SML, is a way of interpreting the expected return-relationship as a risk respectively reward equation. Like Markowitz (1952) viewed mean and variance as the measure of risk respectively reward, beta is seen as the contribution of risk to the optimal portfolio. The main difference is that the SML depicts individual asset risk premiums as a function of asset risk. In theory, the relevant measure of risk of an individual asset is not the variance of the asset, but rather the contribution of risk to the portfolio. A fairly priced asset to its risk should therefore lie on the SML, and like the CAL, under (over) priced assets lie above (below) the SML (Bodie et al., 2014, p. 298-299).

2.5 Sharpe Ratio

The most common method of calculating risk-adjusted returns was developed by William F. Sharpe and is calculated as the excess return over the risk-free rate, divided by the standard deviation of the returns. A higher Sharpe ratio means a higher return compared to the volatility which is rewarded in the measure.

$$Sharpe\ Ratio = \frac{R_i - R_f}{Std.dev}$$

Where,

$$R_i = Return\ of\ individual\ asset$$

$$R_f = Risk\ free\ return$$

$$Std.dev = Standard\ deviation\ of\ the\ returns\ of\ the\ portfolio$$

(Bodie et al., 2014 p. 134).

2.6 Earlier research

The earlier research will cover both long-term returns, optimal portfolios during crashes and the SML.

Jordá et al. (2016) and Jordá et al. (2017) are the originators to much of the long-term price data used in this thesis, and are the authors of the paper named "The Rate of Return on Everything, 1870–2015". In this database, there are rates of return on 25 real and nominal variables, on 17 advanced countries between the years of 1870-2016. The paper introduces long-term data series on housing which on average is half of national wealth in an economy and shows to be the highest returning asset before WW2. After WW2, equities have outperformed housing but only to a much higher volatility. Before WW2, both the risky assets, housing and equities, and the risk-free, interest rates, correlated. After the war, domestic equities seem to correlate more with other, foreign, stock markets, while the correlation with housing fell (Jordá et al. 2016 p. 3-4).

Similar results were found by Lau and McInish (1993), where world equity markets become more correlated and this development accelerated during the crash of 1987. Meric et al. (2015) researched the correlation matrix before and after the crash of 2008 and found that stock markets show an even closer co-movement after the crash. This reduces the possibilities of diversification, and therefore the risk reduction (Meric et al., 2015 p. 97).

Piplack and Straetmans (2009) looked at the co-movements of four different American asset classes, stocks, bonds, T-bills and gold during oil crises in the 1970s and 1980s, the stock market crash 1987 and the terrorist attacks in 2001. Their findings were that the correlation between the asset classes dropped below average levels. The highly correlated, bonds and T-bills shows a decreasing correlation since the 1980s, and gold shows a low correlation with the other asset classes. The authors opened for the possibility of flight-to-quality and flight-to-liquidity effects during financial uncertainty to explain the time-variation in correlation (Piplack & Straetmans, 2009 p. 43).

In *Does the stock market overreact?* from 1985, Nobel laureate Richard Thaler and Werner F. M. De Bondt argues that the stock market actors tend to overract to "unexpected and dramatic news events" (Thaler & De Bondt, 1985, p. 793). An example for this is, according to J. B. Williams, that people tend to overestimate the importance of current earnings and less on the

long-term dividend growth (Williams, 1956). Thaler and De Bondt further state that after a couple of bad earnings reports or other bad news the implication will be that investors become overly pessimistic, and therefore make the stock price fall further than reasonable. This is one of the explanations of the so-called P/E anomaly that states that stocks with very low price/earnings ratios, will generate higher risk-adjusted returns than companies with high P/E (Thaler & De Bondt, 1985 p. 794). The main findings of the paper are that the theory of overreaction holds. The so-called loser portfolios earned roughly 20 per cent excess return over the market, whilst the winner portfolio gained a negative 5 per cent compared to the market. The meaning of this is that "losers", or stocks that had underperformed, tended to make a leap back thanks to the correction of the negative overreaction (Thaler & De Bondt, 1985 p. 799). Thaler and De Bondt also looked at the CAPM-betas of the stocks in the different portfolios. The conclusion was that the winner portfolio had higher beta than the loser portfolio and this would lead to the fact that the loser portfolios would outperform the winner portfolios, while at the same time be significantly less risky if CAPM is correct (Thaler & De Bondt, 1985 p. 801).

Cloninger et al. (2004) tried to empirically plot the SML and the results showed a V-shaped line with the bottom at beta=0, contrary to the traditional theory of a positive slope. This indicates that negative beta assets tend to give a positive return, and they even showed that some negative beta assets generated a higher return than their positive counterpart. Cloninger et al. (2004), explains that the negatively sloped SML for negative beta assets originates from the definition of risk. They use an example of a well-diversified market portfolio; taking a long position should have the same risk as taking a short position, since the variation in price should be the same but with opposite signs. In an efficient market an investor should expect the same return, and the same applies to individual assets (Cloninger et al., 2004 p. 397-399).

3. Method

The approach of the thesis is descriptive with a focus on a quantitative analysis of long-term financial data on a broad variety of assets and the development of correlation and returns. The earlier research done in similar topics will be used as a way of understanding the data and the results.

The quantitative parts will be supplemented by a qualitative analysis of the underlying theories and an attempt of drawing conclusions without the risk of drawing too far-reaching conclusions. By using long-term data and indices, the expectation is to erase any eventual human interaction that would affect the results.

3.1 Empirical method

This section will describe the empirical method and in what way the data has been collected and the different types of limitations done.

3.1.1 Data collection

The data used will only be of secondary character, namely data collected by another research team or by a financial database. Focus lies on getting a wide perspective of asset classes and therefore different types of indices is used to replicate the development of asset prices.

Stocks, housing and interest rates

Most of the data was collected using the Macrohistorical data of Jordà et al. (2017). Here I found the data on stock prices, long- and short-term interest rates and housing prices in different countries. The data extends from 1870 to 2016 with 17 different countries worldwide. The housing prices are constructed using the rent-price approach. This means that the authors calculated a benchmark rent-price ratio on net rental yields based on data from the Investment Property Database (IPD) for the different countries. Then they created time series by adding this ratio to the year-to-year development of house prices. For the stock index, the authors tried to replicate a representative investor. Therefore, they used market-capitalization-weighing and all-share indices in as large extent as possible, to minimize the effect of survivor and selection biases. The data on interest rates were collected from the central banks in the countries, where short-term interest rates were collected from short-term Treasury bills, and the long-term interest rates gathered from long-term government bonds (Jordá et al. 2017). The data is available at http://www.macrohistory.net/data/#DownloadData.

Gold and silver

The gold and silver price were fetched from the site "Measuring Worth" which has gold and silver prices starting in the 13th century. The data is gathered by Samuel H. Williamson and Lawrence H. Officer. The price used is the London market price of gold per fine ounce, given in GBP between 1913 and 1949, and USD in 1950-2013, which was translated to GBP using Measuring Worth's Dollar-Pound exchange rate. The ratio between gold and silver prices was used to turn into nominal prices for silver (Officer & Williamson, 2018).

The data is available at https://measuringworth.com/datasets/gold/result.php and https://measuringworth.com/datasets/exchangepound/result.php.

Oil

British Petroleum has data on oil prices starting in 1861 to 2017. I will use the prices on Crude oil for this thesis and will not compare to other types of oil since this is the most commonly quoted oil type and will give me an indication of the fluctuations and development of the oil prices. The prices are given in dollars, money of the day.

Commodities

Lastly, to capture other types of commodities, I use Federal Reserve's Economic Data on producer price index for all commodities. This will therefore include commodities like oil, gold and silver but also different types of metals, soft commodities and crops. The data collected is monthly and starts in 1913 and is continually updated. All other data is annual, and therefore an annual average is used to transform the data for comparability.

Inflation

No index or price series is accounted for inflation and the interest rates are nominal. This means that no data in the sample is inflation-adjusted and therefore comparable.

Exchange rates

Prices are given in different currencies, but all are calculated into percentage returns before comparison. Therefore, exchange rates are not considered except for the gold prices from 1950 to 2013 which are translated from USD to GBP before calculated into percentage returns.

3.1.2 Optimal portfolios

To compute the optimal portfolios, I divide the data into four-year periods which enables me to calculate expected returns of all nine assets, and their covariance matrix. I use this to produce the risk-adjusted returns by calculating the Sharpe ratio, which is then maximized. The result is portfolios with the highest possible risk-adjusted return during financial crises. The excess return is calculated as the ex-post, or realized, returns minus the average long and short-term interest rate during that four-year period. The optimization is carried out by the Solver-function in Excel, that maximizes the Sharpe ratio with a no-short constraint; a way of prohibiting taking

short positions which seems most reasonable for the common investor. The data used, for the three countries' portfolios, are global and domestic stocks, domestic long- and short-term interest rates, domestic housing and lastly the global commodities. The four-year portfolio is a way of capturing the crises that often last one to two years, but it is also of interest to see how the years before or after affects the portfolios.

3.1.3 Other portfolios

I have constructed eight different portfolios for Sweden, USA and Japan. The optimal 4-year portfolio is the portfolio with weights that maximized the Sharpe ratio every four year. The optimal 100-year portfolio is maximized Sharpe ratio once, during the 100-year period. The Maximum return 100-year portfolio is given weights based on maximized expected return during the 100 years. The minimized variance 100-year portfolio had the variance minimized once during the 100-year period. The equal weights portfolio is a naively diversified portfolio with equal weights given to the different assets that are thought to be available to each investor. The "stocks portfolio" are 100 per cent domestic stocks, the "interest rates portfolio" are 50 per cent domestic short- term interest rates and 50 percent domestic long-term interest rates, and the "housing portfolio" is 100 per cent domestic housing.

3.1.4 Calculation of beta values

The beta is calculated using the formula mentioned in the theory-section. The market returns, r_m, is in the global perspective, the global stock returns, and the domestic stock market returns when I calculate beta values for the U.S, Sweden and Japan. In other words, the beta value of gold for the American investor, is calculated using the covariance between the American stock market returns and gold price returns, divided by the variance of the American stock market returns.

3.1.5 Calculation of global indices

The lack of a long-term global stock and housing price indices forced me to develop my own method to get a realistic global index. Based on the database by Jordá et al. (2017) I made what is called a naive diversification with the different countries' returns. This means that the 15 countries included, gets the same weight in the index, regardless of capitalization of the individual stock markets or size of the country. For example, the MSCI World Index, includes 23 developed countries where the U.S gets a weight of 54 per cent whereas they only get a factor of 1/15, or 6,67 per cent weight by using the naive diversification. This will lead to a residual

compared to passively investing in MSCI World Index. There exists a couple of alternatives to the naive diversification which, for example, would be to give weights based on GDP, market capitalization or base the weights on MSCI's weights. The problems with these are the lack of data or the fact that the magnitudes of economic power has drastically changed over the century. This makes me believe that the naive diversification is an efficient way of approximately mirroring the global returns.

3.2 Limitations

3.2.1 Asset classes

The average private investor will focus on stocks in their portfolio. This is thanks to the popularity of the asset class and the availability of information and possibility to buy and sell easily. I chose to use other asset classes that seems to have similar characteristics. Today there exists different kinds of ETF's (Exchange Traded Funds) that can focus on any obscure asset class while at the same time there exists different kinds of derivatives and structured products that did not exist even 20 years ago. That is why I ended up in the nine asset classes that I use. These are assets that is easily understood, easily traded and will probably be the foundation of the financial market for a long time ahead.

3.2.2 Geographical

I will not make any distinct geographical limitation when I want to compute the global index and analysis. Therefore, I will try to use as many countries found in Jordá et al. (2017) data set as possible. Like earlier stated, the data set contains 17 countries but both Portugal and Italy lacked enough data during the time series which forced me to remove them. The remaining 15 countries are Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, UK, Japan, Netherland, Norway, Sweden and USA. There will be one section that includes a global perspective which will be more descriptive of total returns, but also a section that will focus more on the three countries USA, Japan and Sweden. The reason for this is that I will try to model the perspective of different investors with base in different countries. These countries are of interest mainly because of the importance of the American market for the global economy, the Japanese market because of the geographical and cultural differences compared to North America and Europe, and the low interest rates that has been present for quite some time, and because of the smaller size of Sweden's economy, that still has a well-established financial market.

3.2.3 Time periods

A focus for the thesis is to analyze the behavior of different asset classes during financial turmoil. Therefore, I wanted to include as many crashes as possible. I was able to retrieve data from late 19th century in the Macrohistory database, on oil prices and gold and silver prices but not on the commodity price index. There was some missing data between 1870 and 1913 in the Macrohistory database and therefore I chose to have 1913 as starting date for the data set. By

doing this, I could have, more or less, complete data on as many asset classes as possible. For the same reason I set the end year to 2013. With this, I could have returns on the asset from 1914-2013 which is a period of 100 years which includes several of the most famous financial crises. I also divide the time series into ten- and four-year periods. By doing this, I can analyze the returns and beta during smaller periods of time and look closer at how the assets act during crashes.

3.2.4 Crash periods

USA

The U.S has suffered relatively many financial crashes during the last century. The problem is therefore not to find them, but rather to choose which ones to use. The crashes of 1929-1934, the early 70's, the late 80's with Black Monday, the IT-crash 2001 and lastly The Great Recession in 2007-2009 are considered the largest crashes during this period of time. Except for the crash in 1970s that was started due to the OPEC oil embargo, all were based domestically but spread globally. In the case of the U.S, I will therefore view these as domestic crashes first and foremost, while the 1970s-crash is regarded as global (Mitchell, 2015).

Sweden

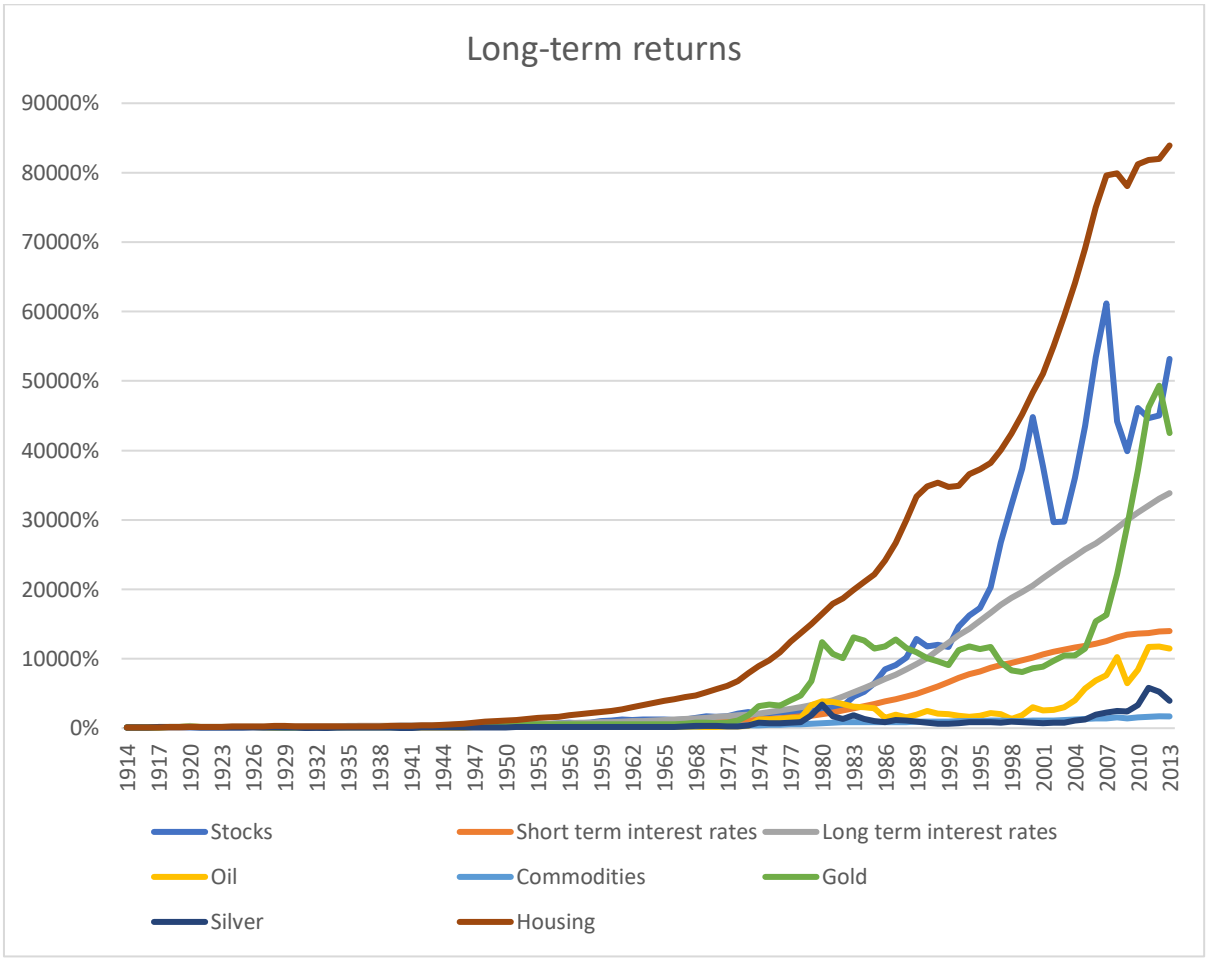
In Sweden, there has been less crashes during this period. Bäckström (2014), pointed out four crashes during the time period of 1914-2013, namely 1920-1922, 1929-1933, 1991-1993 and lastly 2008-2009. Only the crash in 1991-1993 can be viewed as domestic, whilst the others have been more of a global character.

Japan

Japan has had few crashes that lasted over a relatively long period. The first crash came after the end of WW1 where bubbles burst in 1920. The second started in 1927 and is called the Showa Financial Crisis that later turned into the global economic recession in 1930 (Shizume, 2009). The next big crash was not until early 1990s and lasted throughout the decade which is why it is called "The lost decade". This includes 5 crashes according to my division of periods.

4. Results and analysis

4.1 A global overview



Graph 1. Long-term returns for global assets

	Stocks	Short-term interest rates	Long-term interest rates	Oil	Commodities	Gold	Silver	Housing
Arithmetic mean	7,3%	5,1%	6,0%	8,8%	3,2%	7,4%	6,4%	7,1%
Geometric mean	6,5%	5,1%	6,0%	4,9%	2,9%	6,2%	3,7%	7,0%
Standard deviation	12,8%	2,7%	2,3%	35,1%	8,2%	17,3%	25,3%	5,0%
Kurtosis	3,5	3,5	3,8	26,5	10,9	8,7	6,2	3,6
Skewness	-0,3	1,0	1,2	3,8	-0,2	2,1	1,4	0,1
Total return	55677%	13226%	32371%	13315%	1632%	39587%	4213%	84497%

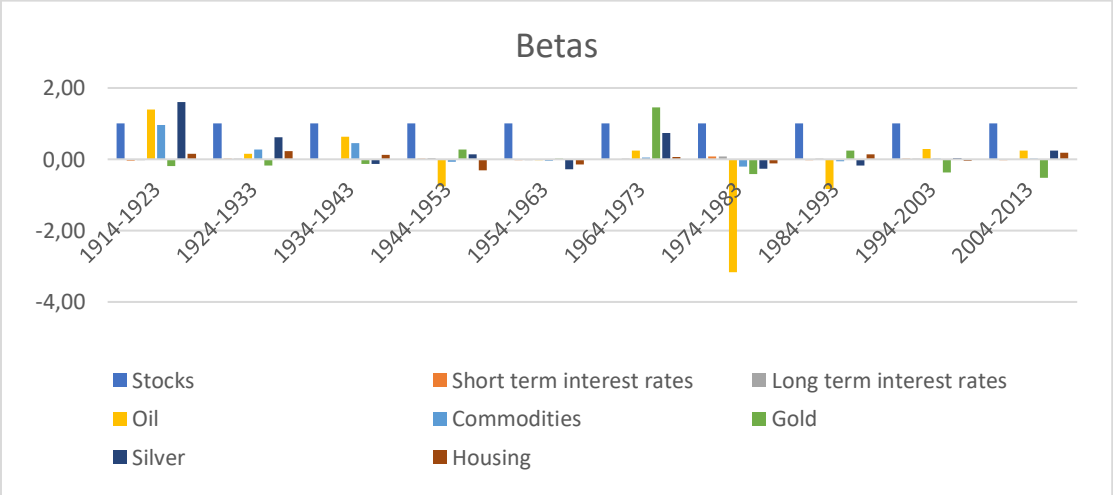
Table 1. Statistical moments for global assets

Even though I excluded some countries and years I, just like Jordà et al. (2016), found that global housing was the asset giving the highest returns at an, geometric, average of seven per cent followed by global stocks at 6.5 per cent. The reason for the high returns in global housing are extraordinary housing returns in Japan, France, Finland, and Spain. The different kinds of commodities, except gold, generated lower returns than having the money placed in "secure" interest rates which is quite remarkable. Looking at the graph and the table, the compounding effect becomes clear with this long investment horizon. Even though there is just a 1 percentage point difference between the average annual return of long-term interest rates and housing, the difference in total return is staggering. Another interesting fact that can be seen in the data is that housing has the third lowest standard deviation after long and short-term interest rate. I can therefore conclude that global housing was an important investment for the last century for risk-adjusted returns, but also as one of the most important factors of the financial crisis in the U.S 2007-2009.

Year/Beta	Stocks	Short-term interest rates	Long-term interest rates	Oil	Commodi-ties	Gold	Silver	Housing
1914-2013	1,00	0,02	0,04	-0,34	0,09	-0,15	0,18	0,06

Table 2. Beta values for global assets over 100 years

For the complete period, the beta values for all of the assets are low. Oil has the largest absolute value, but is also one of two that has a negative value. The theory on correlation on stocks and oil is somewhat debated but one conclusion done by Filis, Degiannakis and Floros (2011) was that the oil market is not a safe haven for protection against stock market turmoil, which is also something that can be seen during the crisis in early 1970s in the U.S. Notable is also that the beta value of fixed-income securities is close to zero which is in line with theory, and they can therefore be seen as a risk-free investment. Looking back at table 1, we can note that the reason for the low beta of interest rates is the low standard deviation. The question is, however, how investing in fixed-income securities has change with the sub-zero rates of today, which is something that I will come back to later. Another classical safe haven is gold. In the total returns in Table 1, gold has quite high average return, but also the third highest standard deviation. Looking at the beta value of gold, there is some negative correlation with global stocks, but it is still very close to zero. Once again, the theory would claim that this is more of a risk-free asset based on this, which is in line with Piplack and Straetmans' (2015) finding of a low correlation of gold to the other asset classes. This makes it interesting to see if that makes gold a sound investment in financial crises.



Graph 2. Beta values for global assets divided into ten-year periods

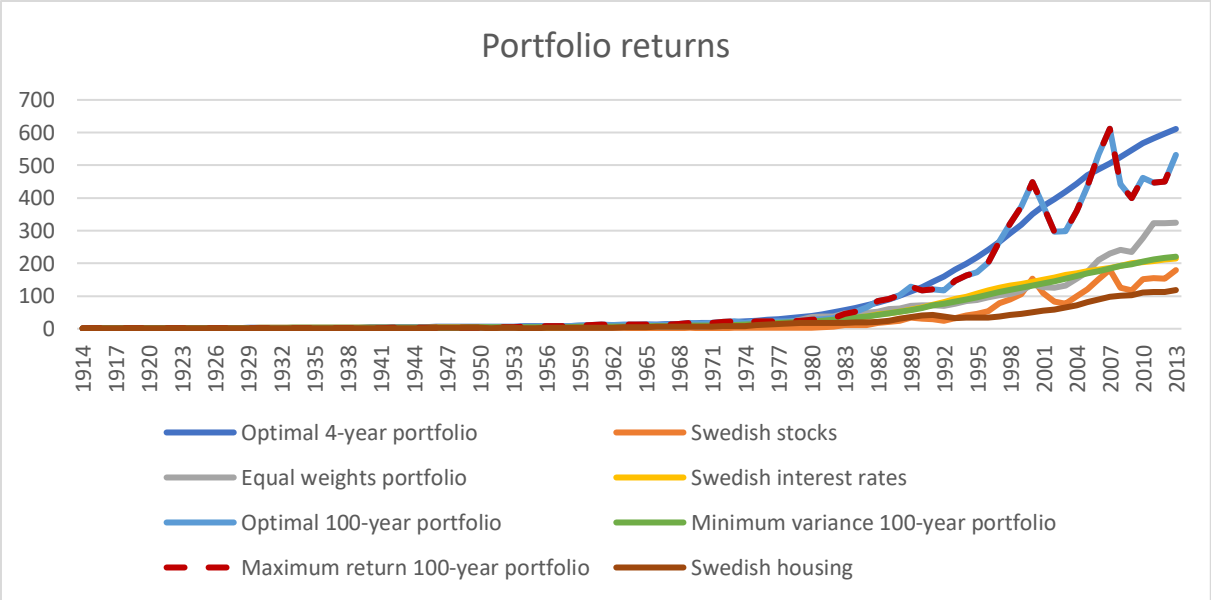
When dividing the calculation of beta into ten-year periods, oil has had the largest fluctuation. During the oil crises of the 1970s and 1980s, the beta fell below -3 which is reasonable when

looking at the returns during the period. Both global stocks and oil had large variances that often went into different directions, but oil still had a total return of 9.8 per cent compared to 9.4 per cent for global stocks during the period of 1974-1983.

4.2 Portfolios

4.2.1 The Swedish investor

The four different periods of crisis are focused in the beginning of the period (1918-1933), and in the end (1990-2009) based on my division; the period in between has been calm when looking at the financial market. Without trying to analyze history too much, this might have been a result of Sweden's neutrality during WW2 and a somewhat low correlation with the global stock market during the oil crises in the 70's and 80's. During this time, the average beta for oil was 0.33 compared to 0.53 for the 100-year period. But still, the small open economy that Sweden has been and still is, was affected by the crash after the end of WW1 and the speculation that followed, the Great Depression in 1929 in the U.S. and the financial crisis of 2007-2009. The only domestic crash has been the one in the early 1990's, based on rapidly driven deregulation and the fact that there had not been any crash in 60 years in Sweden, which made the Swedish government uncapable of handling the situation in the absence of organizational and regulatory structure (Bäckström 2014 p. 26-28).



Graph 3. Total portfolio returns for eight different Swedish portfolios

Here is a comparison of returns on the eight different portfolios. During the period, the highest return is given by the portfolio that had maximized Sharpe Ratio every four year, closely

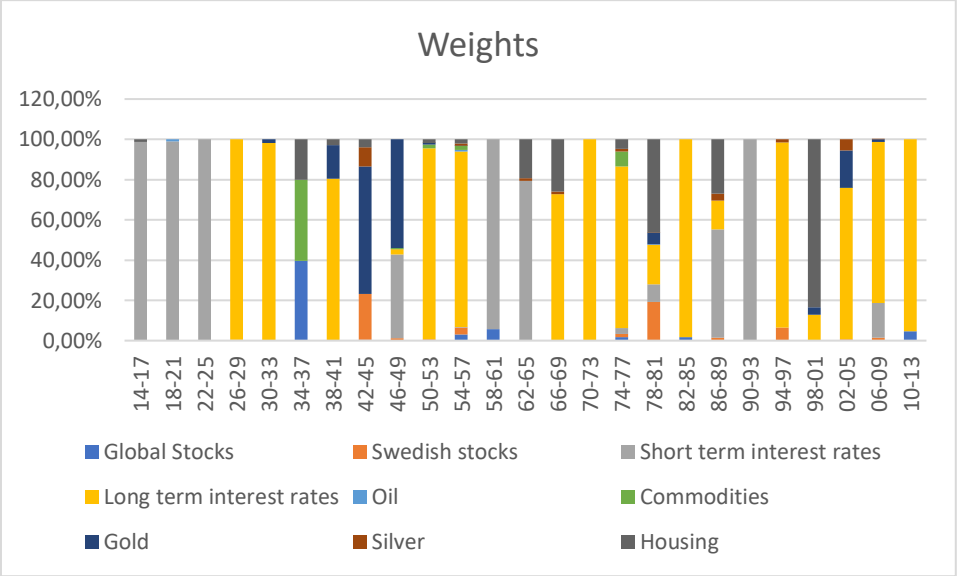
followed by the two portfolios that was maximized over the 100-year period by either Sharpe ratio, or expected returns. Both these portfolios are 100 per cent global stocks. This means that if a Swedish investor was supposed to invest over the 100-year period and only make one investment decision, then the investor should have picked a global, naively diversified, index fund. The reason for the low weights in domestic stocks can be related to this graph; the high volatility with some periods of large corrections gives a high standard deviation and low Sharpe ratio (see also Appendix A, table 23). It is also notable that the optimized four-year portfolio never had a negative return, where 1SEK grew to over 600SEK in the long run, with a high rate of interest rates in the portfolio. In comparison, the portfolio with minimized variance during the 100-year period, only grew to just over 200SEK, and even here, Swedish stocks was excluded. Compared to the global perspective, Swedish housing has underperformed all other portfolios and should therefore, unlike in the global perspective, not be a sound investment in the long run.

	Weights			
	Optimal 4-year portfolio (averages)	Optimal 100-year portfolio	Maximized return 100-year portfolio	Minimum variance 100-year portfolio
Global Stocks	2,3%	100,0%	100,0%	0,3%
Swedish stocks	2,4%	0,0%	0,0%	0,0%
Short-term interest rates	27,8%	0,0%	0,0%	1,2%
Long-term interest rates	48,1%	0,0%	0,0%	81,4%
Oil	0,1%	0,0%	0,0%	0,0%
Commodities	2,1%	0,0%	0,0%	9,6%
Gold	6,6%	0,0%	0,0%	0,3%
Silver	1,0%	0,0%	0,0%	0,0%
Swedish Housing	9,6%	0,0%	0,0%	7,1%

Table 3. The portfolio compositions of the optimized Swedish portfolios

The average weight of interest rates between 1914-2013 in the optimal 4-year portfolio is 76 per cent, while the amount of Swedish stocks is just 2.4 per cent, and even though Swedish housing had a low return, there is almost 10 per cent weight on average. This can be explained by looking at the minimum variance portfolio, where it also was included; the low volatility makes housing a viable option when risk-adjusting, even though it is not when just looking at returns. An investor that wants low volatility, would, on the other hand, not be better off in the minimum variance-portfolio, since the returns in the long run is far too low in comparison (see Appendix A, table 24). Like earlier stated, for the "one-time optimizing Swedish investor", global stocks are the best option and preferred over equal weights. This is thanks to the

relatively high return, and the lower standard deviation thanks to the diversification in several different stock markets. Markowitz (1952) proposed, that diversification is preferred over non-diversification, which is true here; we want geographical diversification with the disclaimer that we do not want too much diversification, since the equal weight portfolio is not preferred over only global stocks.



Graph 4. The portfolio compositions for every period of the Swedish Optimal 4-year portfolio

There are large fluctuations in the weights, since they are re-weighted every four year, without any correlation with earlier period. But the portfolios that were constructed during financial turmoil had one crucial thing in common, a tremendous overweight of interest rates. This is also a fact during periods of non-turmoil, which makes it quite interesting when comparing the return of this optimal portfolio, with the portfolio of interest rates. Global stocks are not a large part of the 4-year portfolios, which can be explained by a larger short-term, than long-term correlation with the Swedish stock market.

	1918-1921	
Portfolio beta = 0,07	**Weight**	**Beta**
Global Stocks	0%	2,53
Swedish stocks	0%	1,00
Short-term interest rates	99%	-0,03
Long-term interest rates	0%	-0,12
Oil	1%	10,44
Commodities	0%	8,42
Gold	0%	2,77
Silver	0%	9,33
Swedish Housing	0%	0,98

Table 4. The Swedish portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1918-1921

When looking at the portfolio structure during the crisis 1918-1921, Swedish short-term interest rates dominated. The optimization is favored by a low correlation, or a low beta value compared to the Swedish stock market. The crisis was based on speculation during an economic boom and a large increase in newly incorporated banks that made loans with low creditworthiness (Bäckström 2014 p. 24). It is of course easy to also note that high interest rates give a low return from housing. The cost of housing is often carried by loans which will deter any returns when the rates are high, and therefore it is both interesting and reasonable to see that the beta value of housing is close to 1. The correlation of the stock market and the housing market during turbulent times seems correlated with the high short-term rates.

	1930-1933	
Portfolio beta = -0,001	**Weight**	**Beta**
Global Stocks	0%	0,81
Swedish stocks	0%	1,00
Short-term interest rates	0%	0,01
Long-term interest rates	98%	0,00
Oil	0%	-0,05
Commodities	0%	0,33
Gold	2%	-0,25
Silver	0%	0,81
Swedish Housing	0%	-0,16

Table 5. The Swedish portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 193-1933

The crisis of 1930 was partly a result of the 1929 crash in the U.S. Sweden had to let go of the gold standard and the central bank had to fight inflation by raising the interest rates. But the financial market in Sweden was also affected by the Kreuger-crash, where the global match and financial empire crashed and left Swedish banks with overdue loans (Bäckström 2014 p. 24-26). The weights have transferred from short to long-term rates which is a result of the larger volatility in short-term rates during this period. The global and the Swedish stock market was relatively highly correlated during this period, which is a result of the global crisis.

	1990-1993	
Portfolio beta = 0,033	**Weight**	**Beta**
Global Stocks	0%	0,66
Swedish stocks	0%	1,00
Short-term interest rates	100%	0,03
Long-term interest rates	0%	-0,03
Oil	0%	-0,36
Commodities	0%	0,00
Gold	0%	0,68
Silver	0%	0,40
Swedish Housing	0%	-0,26

Table 6. The Swedish portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1990-1993

The crisis of early 1990s is usually explained by political uncertainty regarding regulation in the financial markets. Moving from strict regulation to the opposite made it hard for the market participants to adapt (Bäckström 2014 p. 26-28). This crash had lower beta with global stocks than earlier crashes. But the fact that there still is some correlation forces the optimization to not put any weight in global stocks. The interest rates rose, while the housing market crashed which, like stated earlier, has a clear connection. The short-term interest rate during this time was high, at 11.5-13.5 per cent which gave an inverted yield curve as is usual during financial crashes.

	2006-2009	
Portfolio beta = -0,004	**Weight**	**Beta**
Global Stocks	0%	0,89
Swedish stocks	1%	1,00
Short-term interest rates	17%	-0,03
Long-term interest rates	80%	-0,01
Oil	0%	-0,05
Commodities	0%	-0,02
Gold	1%	-0,24
Silver	0%	0,67
Swedish Housing	0%	0,15

Table 7. The Swedish portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 2006-2009

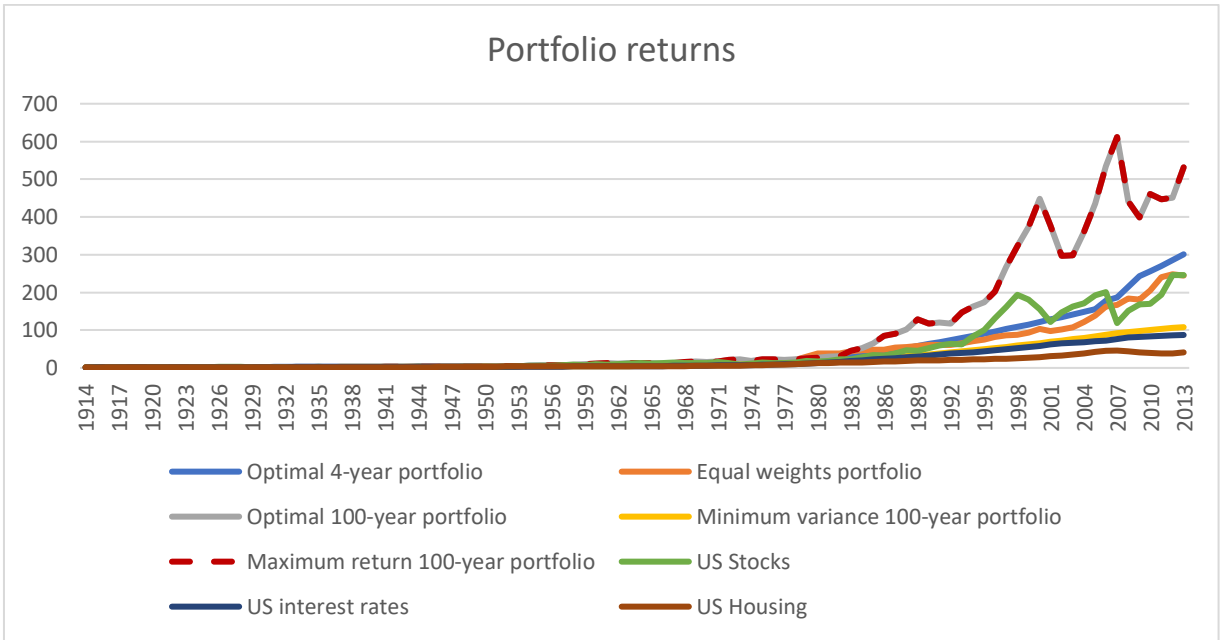
In the latest financial crash, the optimal risk-adjusted portfolio generated a more diversified portfolio than before. Just like in two out of three cases, there is a small weight given to either oil or gold. I would not like to say that these weights really affect the outcome of the portfolio. The total weight in long and short-term interest rates sums up to 97 per cent which is coherent with the earlier portfolios. The crash was based in the U.S housing market and mortgages with low creditworthiness (Mitchell, 2015). There can be connection drawn from all the three crashes during the 20th century where the 1918-1921 crash was based on loans with low creditworthiness, the 1930-1933 crash was a result of turbulence in the U.S, and the 1990-1993 crash had a bust in the housing market. Since there are transitions between long- and short-term interest rates during the different time periods, it is reasonable to have a mix of long and short-term interest rates, during financial crashes.

It is always easy to look in the rear mirror and compute optimal portfolios that beats the market, but like as seen in graph 3, having invested in Swedish stocks, a portfolio of equal shares of the different assets, or a portfolio of both short and long-term interest rates, does not give that much of a difference after 100 years. But even the interest rates generated a higher return than stocks. The conclusion of this should probably be to invest in interest rates and not having to worry about the financial booms and busts. But Sweden, and many parts of the world, are in a period of historically low interest rates that in theory should give negative returns. The best way in the long run would therefore be to perform a naive diversification which would spread the

risks and generate a high return in periods of calm financial environment, and overweight fixed-income securities in times of turbulence, especially when the crash is connected to the housing market.

4.2.2 The U.S investor

The U.S has had several financial crashes during the period of 1913-2013. Some is regarded as the worst in the world history and the effect that the American economy has on the rest of the world is astonishing. The crashes are scattered throughout the period except for the period between 1934-1969 where mostly smaller crashes took place; there are times when the stock market made large losses year-to-year, but the focus will lie on the largest crashes. These crashes were mainly started by oil price fluctuations or boom and busts in the domestic stock market. Like discussed earlier, there are problems in denoting crashes in the U.S as either domestic or global, since domestic crashes in the U.S tend to spread worldwide. But I choose to denote a crash that starts in the U.S as domestic, while the crash that starts in other countries, or by outside factors, like the 1970 oil embargo as global. This leads to five domestic crashes and only one global crash in the sample.



Graph 5. Total portfolio returns for eight different American portfolios

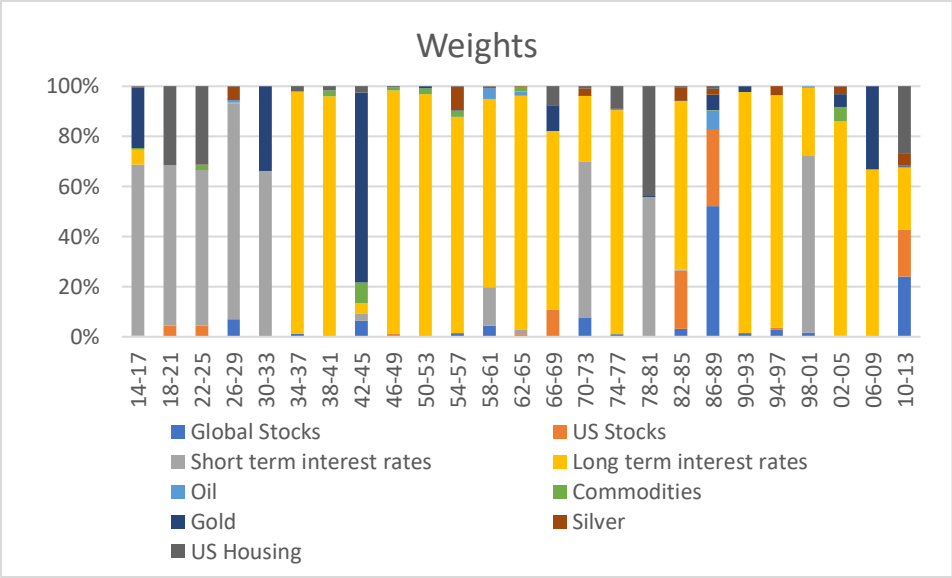
For the American investor only looking at returns, the optimal 4-year portfolio has not been ideal, but rather the ones where only one investment decision was made over the 100-years, namely 100 per cent global stocks. Once again, the optimal risk-adjusted, and the maximized

expected portfolio is the exact same. So just like the Swedish investor, the American investor should have picked a global index fund in the year of 1914, and make no adjustments for 100 years, to receive the highest returns. The optimal 4-year portfolio is only slightly above U.S stocks and the equally weighted portfolio in total returns which is remarkable when compared to Sweden, but even here, the portfolio never has a negative return, and a low standard deviation (see Appendix B, table 26). Lower average interest rates can be one reason for the lower total return in the optimal portfolio in the U.S compared to Sweden (see Appendix B, table 25). Housing is once again the lowest returning portfolio and is not a sound investment for the American investor in the long run.

	Weights			
	Optimal 4-year portfolio (averages)	Optimal 100-year portfolio	Maximum return 100-year portfolio	Minimum variance 100-year portfolio
Global Stocks	5,1%	100,0%	100%	0,0%
US Stocks	4,1%	0,0%	0%	1,0%
Short-term interest rates	13,1%	0,0%	0%	0,0%
Long-term interest rates	61,6%	0,0%	0%	83,8%
Oil	0,7%	0,0%	0%	0,0%
Commodities	1,2%	0,0%	0%	4,9%
Gold	8,0%	0,0%	0%	0,1%
Silver	1,5%	0,0%	0%	0,0%
US	4,6%	0,0%	0%	10,2%

Table 8. The portfolio compositions of the optimized American portfolios

The average portfolio composition for the optimal 4-year portfolio contains close to 75 per cent interest rates, followed by 8 per cent gold, in other words, a large portion of the risk-free asset and a small portion of the safe haven. The amount of global and U.S stocks, and U.S housing is approximately the same but not at significant levels of the total portfolio. The portfolios with a 100-year perspective with optimal levels of returns and risk-adjusted returns are once again 100 per cent global stocks. It is worth noting that global stocks in this paper are not the same as MSCI Global Index or similar indices, since there is a significantly smaller amount of weight given to the American market. This could be an indication of the need for a more diversified index than the ones that give over 50 per cents weight to the U.S stock market, because of the market capitalization, for the investor that wants to receive high risk-adjusted returns in the long run.



Graph 6. The portfolio compositions for every period of the American Optimal 4-year portfolio

The fluctuations in the optimal 4-year portfolio is once again high since there are in total 25 sub-portfolios. As you can see in both this graph and table 8, the amount of oil in the risk-adjusted portfolio is close to none. Gold on the other hand, plays a role in several of the portfolios, and especially during both world wars. The first 20 years included a large portion of short-term interest rates, while the later periods give much weights to long-term interest rates. Just like for Sweden, global stocks are not as valuable in the short-run, as it is in the long run for risk-adjusted returns.

	1926-1929	
Portfolio beta = 0,00002	**Weight**	**Beta**
Global Stocks	7%	0,36
U.S Stocks	0%	1,00
Short-term interest rates	86%	-0,02
Long-term interest rates	0%	0,00
Oil	1%	-0,26
Commodities	0%	-0,06
Gold	0%	0,03
Silver	5%	-0,08
U.S Housing	0%	-0,06

Table 9. The American portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1926-1929

The Black Thursday and the following start of the Great Depression was the beginning of a long period of economic turbulence for the U.S. The crash was mostly an effect of speculation that led to a bubble bursting (Amadeo 2018). Not surprisingly, the optimal risk-adjusted

portfolio during this time did not include any U.S stocks, but some global stocks. There was low correlation seen in the beta value of 0.36 for global stocks which can be an effect of the world not being intertwined in the same way as it is today. The effect of this could therefore be a slower spread of the financial crisis to the rest of the world.

	1930-1933	
Portfolio beta = 0,07	**Weight**	**Beta**
Global Stocks	0%	0,17
U.S Stocks	0%	1,00
Short-term interest rates	66%	-0,05
Long-term interest rates	0%	0,00
Oil	0%	0,59
Commodities	0%	0,00
Gold	34%	0,32
Silver	0%	0,28
U.S Housing	0%	-0,06

Table 10. The American portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1930-1933

The coming years suffered from the aftermath of the large economic and financial crash (Mitchell, 2015). The optimal portfolio contains a majority of short-term interest rates, but also a large portion of gold. The depression lasted over a long period, which could be one reason for the weight given to gold. When looking at financial crises that last only a single year, the incentives to re-weight the portfolio might not be as high as when it lasts over several years, and investors might tend to move to assets with a more tangible intrinsic value like gold, than stocks.

	1970-1973	
Portfolio beta = 0,00004	**Weight**	**Beta**
Global Stocks	8%	-0,28
U.S Stocks	0%	1,00
Short-term interest rates	62%	0,08
Long-term interest rates	26%	0,02
Oil	0%	-0,24
Commodities	0%	-0,16
Gold	0%	-1,40
Silver	3%	-1,08
U.S Housing	1%	0,09

Table 11. The American portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1970-1973

The OPEC's oil embargo of 1973 together with a drop in GDP growth led to a stock market plunge and high inflation (Mitchell, 2015). This is the only U.S crisis that can be viewed as global instead of domestic since the triggering factor was not an effect of bubbles or recession in the American economy. It is therefore interesting to see that there is a similar portfolio structure as the other two crashes with high amounts of short-term interest rates. The fact that the crisis was based in the oil industry might be an explanation to why the portfolio is not different from the others; the U.S economy and industry has historically been highly dependent on oil.

	1986-1989	
Portfolio beta = -0,335	**Weight**	**Beta**
Global Stocks	52%	-0,64
U.S Stocks	30%	1,00
Short-term interest rates	0%	-0,04
Long-term interest rates	0%	-0,05
Oil	8%	0,10
Commodities	0%	0,08
Gold	6%	-0,11
Silver	2%	0,60
U.S Housing	1%	-0,01

Table 12. The American portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1986-1989

The crash in the late 1980s was a result of many moving parts. The Black Monday remains the day where the Dow Jones industrial index had the largest percentage drop, which also was the same day that the U.S attacked an Iranian oil platform. High inflation and high valuation on the stock market were other indicators of the coming crash (Mitchell, 2015). Despite this, or maybe

thanks to the stock market boom in the years before and quick recovery for U.S stocks, the portfolio contains 30 per cent of American stocks. The crash also seems to affect the American stock market since the beta value for global stocks was -0.64. The portfolio beta of -0.335, means that the portfolio is negatively correlated with the U.S stock market, despite the high weight of U.S stocks. This also stands out when compared to the other portfolio betas, where there seems to be a connection between low risk and low beta in financial distress.

	1998-2001	
Portfolio beta = 0,00002	**Weight**	**Beta**
Global Stocks	2%	0,59
U.S Stocks	0%	1,00
Short-term interest rates	70%	-0,01
Long-term interest rates	27%	0,01
Oil	1%	-1,20
Commodities	0%	-0,13
Gold	0%	-0,41
Silver	0%	0,59
U.S Housing	0%	-0,05

Table 13. The American portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1998-2001

The dot-com bubble of 2001 made the stock market plunge almost 45 per cent over two years. For an investor that wanted the highest risk-adjusted return, interest rates were once again the way to go. The crash was based on a bubble in the stock market, but was also intensified by the terrorist attacks in 2001 (Amadeo 2018). There are similarities with the crash in 1987, where valuation in stock markets were high, and there was American military activities in the Middle East, but the optimal risk-adjusted portfolio construction is utterly different. The reason for this is the returns in the years before and after the crash, where American stocks averaged -0.5 per cent for the period of 1998-2001, whilst the average return in 1986-1989 was positive.

	2006-2009	
Portfolio beta = 0,15	**Weight**	**Beta**
Global Stocks	0%	-0,53
U.S Stocks	0%	1,00
Short-term interest rates	0%	-0,02
Long-term interest rates	67%	-0,01
Oil	0%	0,04
Commodities	0%	-0,01
Gold	33%	0,46
Silver	0%	-0,06
U.S Housing	0%	-0,08

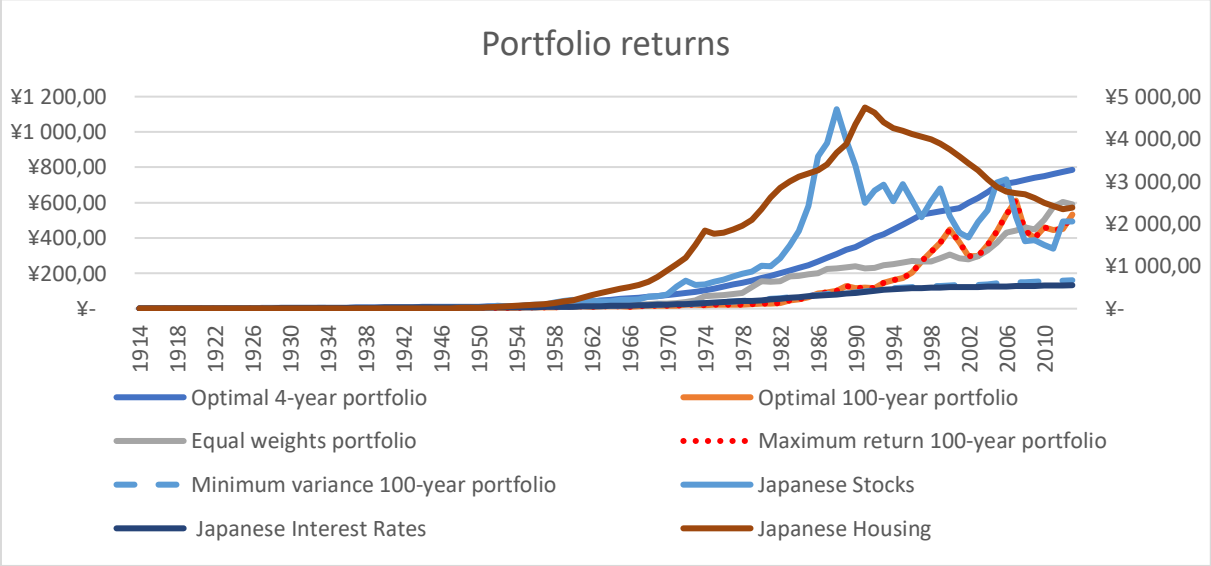
Table 14. The American portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 2006-2009

Financial engineering and loans with low creditworthiness were the tipping point for the next large financial crisis in the U.S (Mitchell, 2015). Gold is just like in the 1930-1933 portfolio a large part of the optimal portfolio. There is a transit from short- to long-term rates compared to the 1930-1933 portfolio, which can be explained by the higher long-term rates during 2006-2009. The crisis made a huge hit on the stock market both domestically and globally which makes it reasonable to not have any weights in stocks. Both silver and oil had large returns during this time, but the high standard deviations made them unfit for the portfolio.

In two of six portfolios, there was one third gold, while there was more than 60 per cent of fixed-income securities in all portfolios except one. The portfolio without interest rates had an overweight of global stocks, which could either show a less globally intertwined stock market than today, which Lau and McInish (1993) also argued, or the fact that there was high returns before and after the crash. Like stated earlier, the U.S has had lower interest rates compared to Sweden, which is the reason for lower risk-adjusted returns.

4.2.3 The Japanese investor

Japan stands out compared to the other two countries by the way their crashes seems to last for a relatively long period of time. There have only been three crashes during the century, but my four-year division creates five different crash portfolios. Even though Japan can be viewed as geographically and culturally different from North America and Europe, their developed financial system is globally important and intertwined. But the most interesting part about Japan's financial system compared to the other two countries, is the low interest rates that has been present since late 1990s.



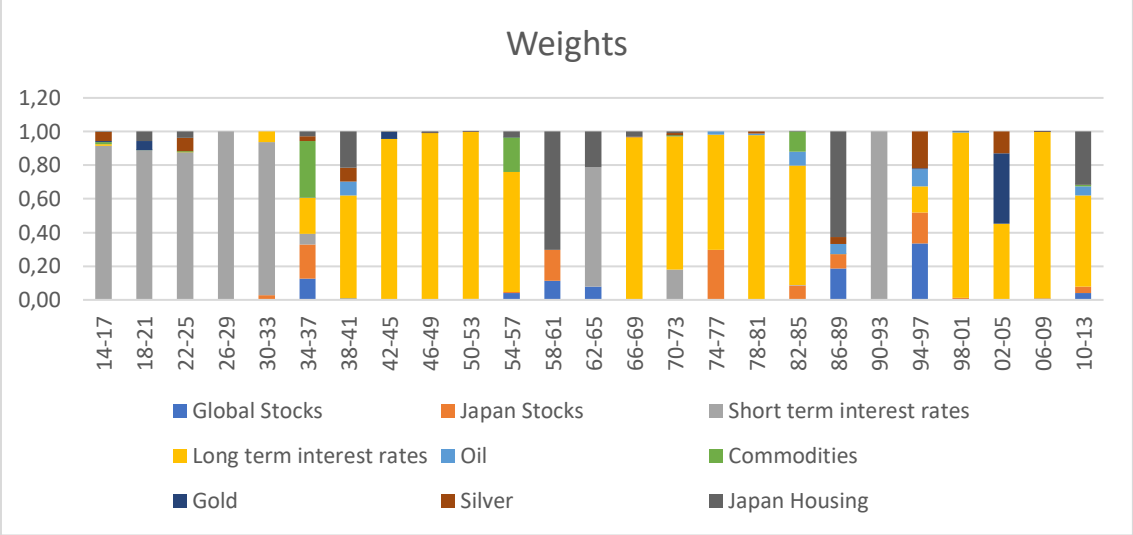
Graph 7. Total portfolio returns for eight different Japanese portfolios

It is obvious when looking at the graph that Japan suffered a financial crisis during 1990s. Housing (depicted on the right axis in the graph) had tremendous returns over the century, in which ¥1 in 1914 grew to close to ¥5000 in 1991. After that, housing dropped almost 50 per cent at the end of the period; still having the highest total return between 1914 and 2013 out of all portfolios. Japanese stocks displayed a similar pattern but topped out in late 1980s, only to get outperformed in the end by the optimal 4-year portfolio, the equal weight-portfolio and what once again is 100 per cent global stocks in the maximized 100-year portfolios. The Equal weights portfolio has had high returns, thanks to the large returns in stocks and housing. But there is also an inherited volatility which makes it unsuitable for a risk-adjusted investor (see Appendix C, table 28). Interest rates have had low returns during the century, partly, because the central bank setting rates at close to zero, in the 1990s.

	Weights			
	Optimal 4-year portfolio (averages)	Optimal 100-year portfolio	Maximum return 100-year portfolio	Minimum variance 100-year portfolio
Global Stocks	4,1%	100,0%	100,0%	3,6%
Japanese Stocks	4,9%	0,0%	0,0%	0,0%
Short-term interest rates	23,5%	0,0%	0,0%	15,1%
Long-term interest rates	48,5%	0,0%	0,0%	71,4%
Oil	1,8%	0,0%	0,0%	0,0%
Commodities	2,8%	0,0%	0,0%	8,6%
Gold	2,2%	0,0%	0,0%	0,6%
Silver	2,8%	0,0%	0,0%	0,3%
Japanese Housing	9,5%	0,0%	0,0%	0,4%

Table 15. The portfolio compositions of the optimized Japanese portfolios

Not surprising, the amount of Japanese stocks and housing in the optimal 4-year portfolio is relatively low despite the high returns because of the high volatility (see Appendix C. table 27). On average, there has been 72 per cent interest rates in the portfolio, which is in line with the other two countries. This means that interest rates have been an important asset for risk-adjusted returns, despite their low return the last decades. Once again, the optimal 100-year portfolio and Maximum return 100-year portfolio contains 100 per cent global stocks. This is because of the high return with relatively low volatility.



Graph 8. The portfolio compositions for every period of the Japanese Optimal 4-year portfolio

The weights in the optimal 4-year portfolio shows a similar pattern to the portfolios in Sweden and the U.S. In the first five periods, short-term interest rates are overrepresented, only to get replaced by long-term interest rates for the rest of the period. Despite the low interest rates, fixed-income securities make up a significant part of the last four portfolios.

	1918–1921	
Portfolio beta = 0,0001	**Weights**	**Beta**
Global Stocks	0%	0,00
Japanese Stocks	0%	1,00
Short-term interest rates	89%	0,00
Long-term interest rates	0%	0,00
Oil	0%	0,06
Commodities	0%	-0,02
Gold	5%	-0,06
Silver	0%	-0,03
Japanese Housing	6%	0,08

Table 16. The Japanese portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1918-1921

Japan's involvement in World War 1 created an economic upturn in mid-1910s only to be followed by a recession in 1920 (Shizume, 2009). The optimal risk-adjusted portfolio was dominated by short-term interest rates. It is interesting that all assets had absolute beta values of less

than 0.1, which gives the portfolio a beta of close to zero. It was therefore possible to receive high returns, free of risk during this period.

	1926-1929	
Portfolio beta = 0,04	**Weights**	**Beta**
Global Stocks	0%	0,50
Japanese Stocks	0%	1,00
Short-term interest rates	100%	0,04
Long-term interest rates	0%	0,00
Oil	0%	0,23
Commodities	0%	-0,03
Gold	0%	0,04
Silver	0%	-0,03
Japanese Housing	0%	0,46

Table 17. The Japanese portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1926-1929

The recession continued and turned into the Showa Financial Crisis of 1927, which was a consequence of financial instability and bad loans issued by the financial institutes (Shizume, 2009). Just like in 1918-1921, Japan had an inverted yield curve because of the instability, and insecurity of the future banking system. The short-term interest rates where therefore higher than the long-term interest rates which did not change until the middle of 1930s.

	1930-1933	
Portfolio beta = 0,04	**Weights**	**Beta**
Global Stocks	0%	0,05
Japanese Stocks	3%	1,00
Short-term interest rates	91%	0,01
Long-term interest rates	6%	-0,01
Oil	0%	0,08
Commodities	0%	-0,05
Gold	0%	0,33
Silver	0%	0,24
Japanese Housing	0%	0,06

Table 18. The Japanese portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1930-1933

Unlike the case of the U.S crisis in the same period, gold is not a part of this portfolio. My theory of long recessions and high transitions to gold is therefore not accurate in this case. According to Shizume (2009), the depression in 1930-1931, also called the Showa Depression, was not domestic but rather a result of imported deflation and falling demand on export goods. The result was a portfolio with 97 per cent interest rates, and the small portion of long-term interest rates indicates that the yield curve is returning to having the regular upward slope.

	1990-1993	
Portfolio beta = -0,01	**Weights**	**Beta**
Global Stocks	0%	0,28
Japanese Stocks	0%	1,00
Short-term interest rates	100%	-0,01
Long-term interest rates	0%	-0,02
Oil	0%	-0,17
Commodities	0%	-0,01
Gold	0%	0,37
Silver	0%	0,54
Japanese Housing	0%	-0,43

Table 19. The Japanese portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1990-1993

The next financial crisis in Japan is the start of what has come to be called “The Lost Decade” because of the large erase of value in both the stock market and the housing market. Japan entered 1990s with the largest and strongest financial institutions and extraordinary asset returns

which ended with a burst of the bubble (Patrick, 1999; Nakaso, 2001). What followed was low growth rate in GDP and lower corporate plant and private housing investments (Horioka, 2006). The yield curve was flat, and the optimal risk-adjusted portfolio was completely focused on short-term interest rates.

	1994-1997	
Portfolio beta = -0,00	**Weights**	**Beta**
Global Stocks	33%	-0,46
Japanese Stocks	18%	1,00
Short-term interest rates	0%	0,02
Long-term interest rates	16%	0,03
Oil	10%	0,21
Commodities	0%	0,08
Gold	1%	0,07
Silver	22%	-0,26
Japanese Housing	0%	0,02

Table 20. The Japanese portfolio composition for the optimal risk-adjusted portfolio during the financial crisis of 1994-1997

The second part of the depression was characterized by concern for deflation. The typical central bank measure is to lower interest rates to increase consumption, which the Bank of Japan did. In the end of the portfolio period, short-term interest rates were below 0.5 per cent which gives us a portfolio composition of only 16 per cent interest rates. The depression was purely domestic and global stocks had a large negative beta value, but the portfolio had still a beta of close to zero, thanks to the diversification.

Unfortunately, for this paper, there has not been any more crises in Japan after the lowering of the interest rates to levels which can be seen in both the U.S and Sweden today. The last portfolio gives a glimpse of how a crash portfolio may look like when we have these low levels interest rates. The first four portfolios had similar compositions like the one in Sweden and the U.S, which indicates similarities in portfolio construction over a long period of time despite the differences in the three countries' financial, economic and political system. To receive the highest possible risk-adjusted returns in financial crises in Japan, an investor should try to construct a portfolio with a beta value close to zero. If there are any conclusions to be made from the last portfolio, then it would be that in domestic crashes with low interest rates, the Japanese investor should invest in global stocks and commodities (oil, silver and gold). Looking back at the long-

term portfolio returns in graph 7, the best recommendation would be to diversify equally in the investable assets. The high returns in housing and stocks was followed by large price drops, which is an indication of a highly volatile financial market, making it inefficient to stay invested in a single asset class. So once again, Markowitz (1952) was right regarding the diversification.

4.2.4 The case of all three countries

	Type of crisis	Weights >10 %
	Sweden	
1918–1921	Global bust, bankcrisis	Short-term interest rates
1930–1933	Global financial crash	Long-term interest rates
1990–1993	Domestic housing crisis	Short-term interest rates
2006–2009	Global financial crash	Long-term interest rates, Short-term interest rates
	The U.S	
1926–1929	Domestic stock market crash	Short-term interest rates
1930–1933	Domestic economic crash	Short-term interest rates, Gold
1970–1973	Oil embargo and low GDP growth	Short-term interest rates, Long-term interest rates
1986–1989	Domestic stock market crash	Global Stocks, U.S Stocks
1998–2001	Domestic stock market crash	Short-term interest rates, Long-term interest rates
2006–2009	Global financial crisis, Domestic housing crisis	Long-term interest rates, Gold
	Japan	
1918–1921	Global bust	Short-term interest rates
1926–1929	Domestic financial instability	Short-term interest rates
1930–1933	Global financial crash	Short-term interest rates
1990–1993	Domestic financial crash	Short-term interest rates
1994–1997	Domestic economic crash	Global stocks, Japanese stocks, Long-term interest rates, Oil, Silver

Table 21. A summary of all the types of crashes in the sample, and the assets with weights >10 % given in the risk-adjusted portfolios

The result of the portfolio optimization is seen in this table together with the main reasons for the financial crises in each country. There is an overweight on interest rates, and mostly short-term interest rates. The reason for this seems quite clear; there is often less volatility in the interest rates, and they do sometimes seem to increase during periods of financial turbulence. In the last 60 years, every American recession was preceded by an inverted yield curve, meaning that the yield on short-term interest rates raises above the yield on long-term interest rates (Bauer & Mertens, 2018). If this is the case for the rest of the world, it seems reasonable to have more short- than long-term interest rates in a crash portfolio. Looking back at Sweden, the country seems to be affected by the global financial environment, maybe more now than ever. The result from the portfolios shows that fixed-income securities have been the most reliable asset during financial turmoil. The conclusion on which of long- and short-term interest rate are

superior, is that in domestically focused crashes, short-term rates are better and in globally based crashes, long-term rates are better. An explanation could be that the inverted yield curve is more common during domestic crises when the central banks tend to rise interest rates to prevent deflation, and longer interest rates may fall as a result of insecurity. Moving on to the American investor, the same holds; fixed-income securities are the most efficient asset during financial turmoil. But there is also some gold and even stocks in the portfolios which makes it harder to say whether there is an optimal portfolio during all times of financial turmoil. Trying to investigate how a domestic or global crash differs in the case of the U.S is hard since most domestic crashes turn global. On the other hand, this will probably not change in the foreseeable future which makes the analysis the same for coming crashes. Lastly, the Japanese portfolios had a consistent composition of short-term interest rates during financial crashes in between 1918 and 1993. After that, the Bank of Japan lowered the interest rates to levels that many parts of the world have today. With the low interest rates, the optimal risk-adjusted portfolio was well-diversified in global stocks, oil, gold, silver, long-term interest rates and domestic stocks in the period of 1994-1997.

Unlike Japan, Sweden and the U.S have never suffered a financial crash during their time with interest rates at levels below one percent. Because of that, it is reasonable to think that what has been optimal during the last 100 years might not be optimal now. The data shows that there have been periods of temporarily low rates before, which makes it fair to assume that there is going to be higher rates in the future, especially if there are increases in inflation. But to see what a portfolio without interest rates would look like, I made alternative portfolios for the period 2006-2009 for both the U.S and Sweden.

	Sweden			The U.S	
Portfolio beta = 0,03	**Weights**	**Beta**	Portfolio beta = 0,3	**Weights**	**Beta**
Global Stocks	0%	0,89	**Global Stocks**	17%	-0,53
Swedish stocks	0%	1,00	**U.S Stocks**	0%	1,00
Oil	0%	-0,05	**Oil**	1%	0,04
Commodities	0%	-0,02	**Commodities**	0%	-0,01
Gold	32%	-0,24	**Gold**	82%	0,46
Silver	0%	0,67	**Silver**	0%	-0,06
Swedish Housing	68%	0,15	**U.S Housing**	0%	-0,08

Table 22. Alternative optimal risk-adjusted portfolios for Sweden and The U.S during the financial crash of 2006-2009

Both countries have transferred to a large portion of gold, especially the U.S. Gold being a safe haven might be a self-fulfilling prophecy where investors tend to buy gold to hedge in periods of turmoil, which raises the price and gives higher returns for everyone except the last one selling. Swedish housing gets a large weight in this portfolio which has not been seen before. For all three countries and all time periods, housing has never been a good choice for a risk-adjusted portfolio, despite the asset having the highest global returns, the highest return in Japan and the third lowest standard deviation. But this has not been enough to give an over-weight of housing in the periods of crisis; the excess return over interest rates has not been adequate to account for the excess volatility over fixed-income securities.

5. End discussion and suggestions for further research

Both Jordá et al. (2017) and I found that housing was the highest returning asset in the global and Japanese perspective, but a crucial difference was that they found housing to be an optimal asset for diversification. In times of crisis, housing was not given a weight larger than 10 per cent in any of the portfolios, despite the high returns and low standard deviation over the long period of time. The reason is simply that the standard deviation was not low enough to compete with fixed-income securities, and especially short-term interest rates which was the undoubtedly most common asset in the portfolios. Several times, I mentioned the inverted yield curve. This seems to be very important for a topic like this; the average short-term interest rate is lower and has a higher standard deviation than long-term interest rates do in 100 years. But in times of crisis and crash, the yield curve tends to get inverted and fixed-income securities with low duration tend to have a higher yield than long-term bonds. The explanation for this can be that the central banks uses the interest rates to combat inflation and recession. Another explanation is simply that investors are uncertain about the future.

The problem, for an investor reading this paper, with the historically low interest rates might be temporary, nonetheless, it cannot be ignored. When computing alternative portfolios during the last financial crisis, gold was re-established as a safe haven, and in the last Japanese portfolio when the Bank of Japan started to lower the interest rates, both domestic and global stocks was given the highest weights, and the commodities oil and silver stood for a third of the total weight. It would be interesting to do similar computations, without interest rates, during the other crisis to see if there are any patterns, but it is definitely fascinating to see that even when the fixed-income securities were included, but at low levels; only 15 per cent of the portfolio was interest rates. We might therefore be at a point in time where historical data will not give us the answer for the future, which however is reasonable when considering the extensive range of financial assets that exists today; from the possibilities of diversifications in ETF, to crypto currencies and other assets that is completely different from what was available for an investor in early 20th century.

There are elements of arbitrariness in choosing the 4-year periods. To further research the topic, optimal portfolios during only times of financial distress would be alluring to compute. The problem is the lack of data to either compute beta or standard deviation which made the method

used in this paper an efficient way of solving those problems. Another option would be to extend the periods to for example 10 years. This creates less focus on financial crashes and more on the years before and after which could be interesting to further investigate Thaler and DeBondt's (1985) theories. The possibilities that we have today regarding numbers of asset classes and ways of diversification has never been seen before. Therefore, looking at individual markets as a possibility of investing would be interesting, and see if, for example a Swedish investor would be better of investing in the U.S, or even in an emerging market if that would give high risk-adjusted returns thanks to diversification.

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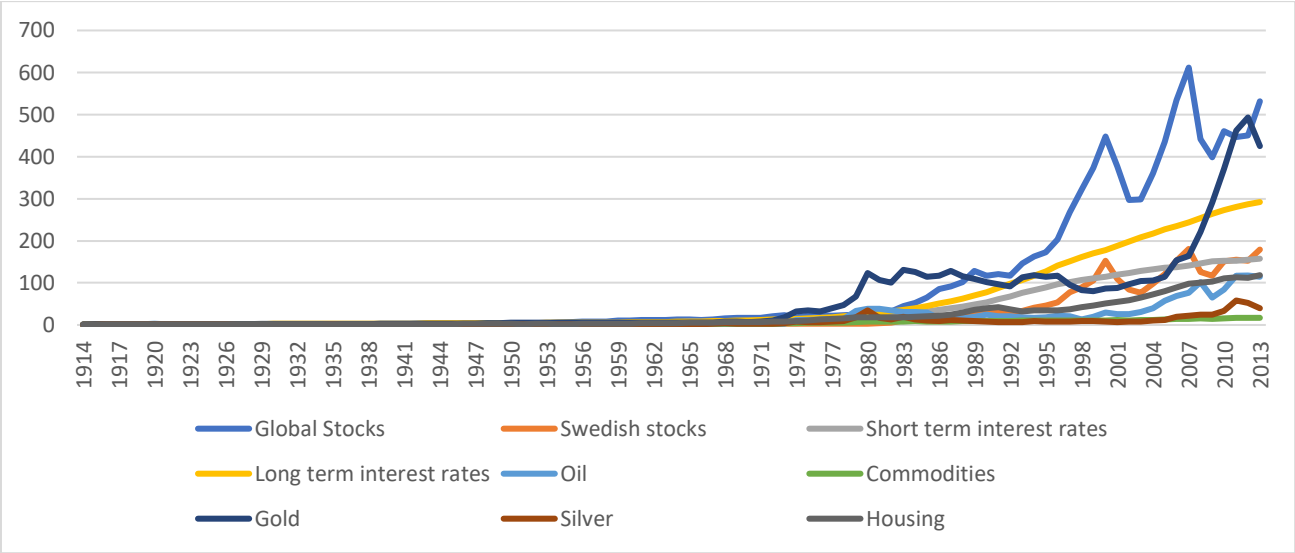
Appendix A - Sweden



Graph 9. Swedish long-term returns on 9 different asset classes

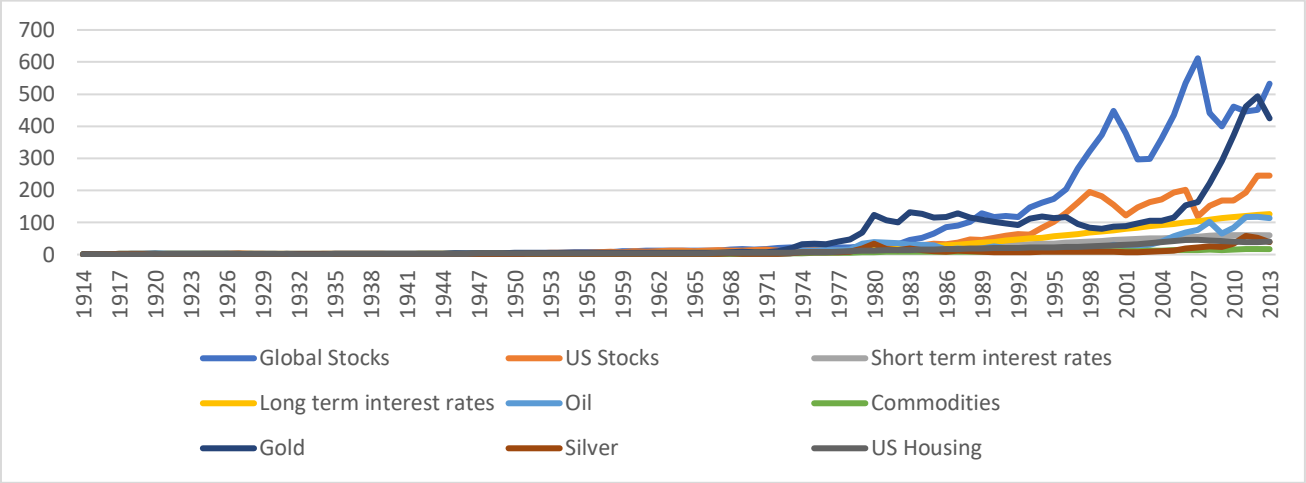
	Global Stocks	Swedish stocks	Short term interest rates	Long term interest rates	Oil	Commodities	Gold	Silver
Arithmetic mean	7,39%	7,60%	5,23%	5,90%	9,00%	3,26%	7,41%	6,54%
Geometric mean	6,60%	5,71%	5,19%	5,86%	5,07%	2,92%	6,23%	3,88%
Standard deviation	12,83%	20,53%	2,98%	3,02%	35,21%	8,22%	17,38%	25,37%
Kurtosis	3,55	5,57	4,05	3,06	26,43	10,92	8,60	6,18
Skewness	-0,36	0,75	1,18	1,07	3,80	-0,26	2,13	1,39

Table 23. Statistical moments of the 9 different Swedish asset classes

	Optimal 4-year portfolio	Optimal 100-year portfolio	Equal weights portfolio	Maximum return 100-year portfolio	Minimum variance 100-year portfolio	Swedish Stocks	Swedish Interest Rates	Swedish Housing
Arithmetic mean	6,67%	7,27%	6,29%	7,27%	5,58%	7,26%	5,56%	5,20%
Geometric mean	6,63%	6,48%	5,95%	6,48%	5,54%	5,32%	5,52%	4,89%
Standard deviation	3,00%	12,82%	8,78%	12,82%	2,78%	20,71%	2,93%	7,93%
Kurtosis	2,63	3,52	8,67	3,52	2,48	5,44	3,46	7,21
Skewness	0,81	-0,33	1,51	-0,33	0,70	0,72	1,13	-0,87

Table 24. Statistical moments of the Swedish portfolios

Appendix B - USA



Graph 10. U.S long-term returns on 9 different asset classes

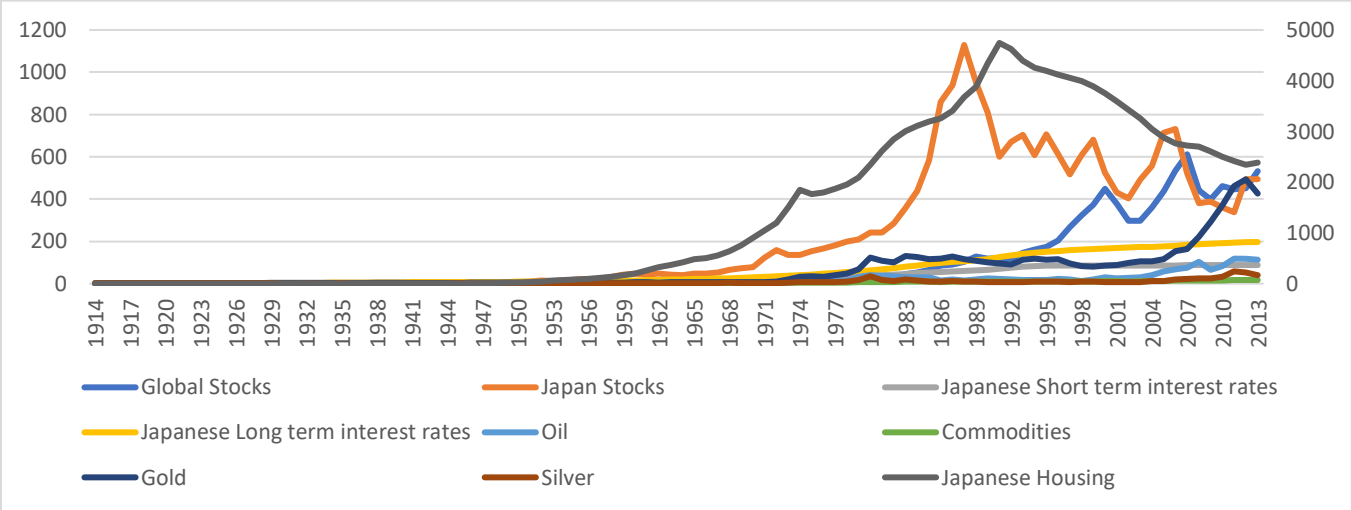
	Global Stocks	US Stocks	Short term interest rates	Long term interest rates	Oil	Commodities	Gold	Silver	US Housing
Arithmetic mean	7,39%	7,25%	4,23%	5,00%	9,00%	3,26%	7,41%	6,54%	3,92%
Geometric mean	6,60%	5,45%	4,19%	4,96%	5,07%	2,92%	6,23%	3,88%	3,77%
Standard deviation	12,83%	18,74%	3,15%	2,63%	35,21%	8,22%	17,38%	25,37%	5,65%
Kurtosis	3,55	3,03	4,79	4,56	26,43	10,92	8,60	6,18	4,66
Skewness	-0,36	-0,52	1,20	1,33	3,80	-0,26	2,13	1,39	0,60

Table 25. Statistical moments of the 9 different U.S asset classes

	Optimal 4-year portfolio	Equal weights portfolio	Optimal 100-year portfolio	Minimum variance 100-year portfolio	Maximum return 100-year portfolio	US Stocks	US interest rates	US Housing
Arithmetic mean	0,06	0,06	0,07	0,05	0,07	0,07	0,05	0,04
Geometric mean	0,06	0,06	0,06	0,05	0,06	0,06	0,05	0,04
Standard deviation	0,03	0,08	0,13	0,02	0,13	0,19	0,03	0,06
Kurtosis	3,61	12,68	3,52	3,46	3,52	3,02	4,87	4,69
Skewness	1,15	2,08	-0,33	0,96	-0,33	-0,54	1,30	0,60

Table 26. Statistical moments of the U.S portfolios

Appendix C - Japan



Graph 11. Japanese long-term returns on 9 different asset classes (housing depicted on the right-axis)

	Global Stocks	Japan Stocks	Japanese Short term interest rates	Japanese Long term interest rates	Oil	Commodities	Gold	Silver
Arithmetic mean	7,39%	9,23%	4,61%	5,46%	9,00%	3,26%	7,41%	6,54%
Geometric mean	6,60%	6,21%	4,54%	5,43%	5,07%	2,92%	6,23%	3,88%
Standard deviation	12,83%	26,44%	3,80%	2,38%	35,21%	8,22%	17,38%	25,37%
Kurtosis	3,55	5,29	1,61	2,65	26,43	10,92	8,60	6,18
Skewness	-0,36	0,94	0,00	-0,32	3,80	-0,26	2,13	1,39

Table 27. Statistical moments of the 9 different Japanese asset classes

	Optimal 4-year portfolio	Optimal 100-year portfolio	Equal weights portfolio	Maximum return 100-year portfolio	Minimum variance 100-year portfolio	Japanese Stocks	Japanese Interest Rates	Japanese Housing
Arithmetic mean	0,07	0,07	0,07	0,07	0,05	0,09	0,05	0,10
Geometric mean	0,07	0,06	0,07	0,06	0,05	0,06	0,05	0,08
Standard deviation	0,04	0,13	0,09	0,13	0,02	0,26	0,03	0,21
Kurtosis	11,22	3,52	8,48	3,52	2,47	5,27	1,75	8,45
Skewness	2,17	-0,33	1,68	-0,33	-0,38	0,92	-0,27	1,97

Table 28. Statistical moments of the Japanese portfolios