Swaption Strategy

versus

Dynamic Delta

Replicating Strategy

Two interest rate hedging strategies compared…

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Management summary

Pension funds need to hedge the interest rate risk of the liabilities. To do this, several alternatives exist. One of them is hedging by swaptions. However, the application of this strategy can be performed through a buy and hold swaption strategy or a dynamic delta replicating strategy. As the implied volatility in the swaption market may overreact to some market circumstances and swaptions may be priced for insurance properties it provides, it might be worth to replicate the swaption.

This research has been done to compare the swaption strategy with the dynamic delta replicating strategy. This is done by using historical data. The simulations for this research are based on different costs structures and different rebalancing periods. Trading costs of dynamic delta replicating strategy overtakes the swaption trading costs. Saving trading costs is possible by decreasing the rebalancing frequency. The counter effect is the increase of the hedging error.

After giving information about the periodical development of the strategies, the comparison of the strategies is done for results at expiry date of each analyzed swaption. The difference between the results of both strategies is affected by implied volatilities and the direction of the underlying interest rate move. This is best observed in the simulations of the crisis period. To complete the research, individual scenarios are analyzed.

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1 Introduction

The funding ratio of pension funds is defined as the ratio of assets over liabilities. The value of the assets and the liabilities on the balance sheet is affected by fluctuating interest rates. Assets are affected through the investments in bonds, while the liabilities are affected through the regulations which require to assess liabilities at fair value. The duration of the liabilities (10-20 years) is typically higher than the duration of the assets (5-7 years). In addition, the value of the bond holdings is typically lower than the value of the liabilities. Due to these two characteristics, the asset side of the balance sheet reacts with a different magnitude to interest rate changes than the liability side of the balance sheet (Engel, Kat and Kocken September 2005). In case of declining interest rates, the value of the liabilities increases much more than the assets do. This leads to a deterioration of the funding ratio.

In order to prevent the funding ratio to drop by adverse interest rate movements, pension funds may choose to (partly) hedge this risk. To do this, there are several ways. Liabilities can be hedged by receiver swaps or receiver swaptions. If the counterparty risk is ignored, swap contracts provide the possibility of a perfect hedge. Receiver swaps hedge the liabilities for interest rate decreases, but also in case of interest rate increases, effectively giving up any possible gains. Unlike swaps, swaptions provide protection for adverse movements of the interest rate, but keep the upside potential in case of interest rate increases. Swaptions are purchased at a premium, which is lost if the interest rate doesn't move.

PGGM is interested in the possible use of swaptions as a hedge. Nevertheless, PGGM is aware of the impact that the loss of the swaption premium can have on the funding ratio, especially when the premium is lost multiple years in a row. PGGM has chosen to investigate whether a dynamic delta replication strategy (DDRS) of the swaption could be more efficient than purchasing the swaption outright. The possible cost-efficiency of such a strategy is investigated in this thesis. Elements that will be part of the comparison comprise amongst others:

- Trading costs
- Hedging error
- Rebalancing period
- Economic circumstances
    - Volatility
    - Stress

The efficiency of one strategy versus the other strategy depends on the development of variables like the underlying interest rate, the implied volatility (IV) and the trading costs of the DDRS. If the realized volatility turns out to be lower than the implied volatility at purchase, the swaption was priced too expensive. In that case the DDRS could be more efficient than the swaption strategy. In the opposite case, the swaption could be more profitable. The swaption strategy implies a buy-and-hold strategy: no further action is needed until expiration. For the DDRS the portfolio has to be rebalanced periodically, which requires action by traders. Due to the frequent involvement of traders, there may be behavioral failings as well, but this risk is not further taken into account in this thesis. The DDRS has the practical disadvantage of the need to trade swaps in stressed periods when it is hardly tradable. At those moments, when the hedge is needed so much, the hedge is not available or it is available at very high trading costs. The swaption strategy doesn't face that problem to that extent due to its low number of trades.

In this paper, a research can be found on how to replicate the swaption strategy and find out whether a replicating strategy offers any advantage. In chapter two, a clear explanation of swaps and swaptions can be found. Besides that, a technical explanation of delta replication will be given. In chapter three the data which is used in this research will be explained. In chapter four, you will find an explanation of the performed simulations and the analysis regarding the simulations. Furthermore, this chapter includes sensitivity analysis and single simulation explanations for special cases. In chapter five, summary and concluding remarks are included. Furthermore, suggestions for further research will be given.

2 Problem definition

2.1 Liabilities of pension funds

The Dutch Central Bank (De Nederlandsche Bank, or DNB) is the supervisory organization for pension funds. They monitor the financial situation of pension funds and require them to be solvent or to become solvent as soon as possible if that is not the case. The solvency of a pension fund is measured as the ratio of assets over liabilities, the so called funding ratio. The required funding ratio by DNB is 105%. As soon as the funding ratio falls below 105%, DNB will require measures to be taken by the pension fund. On top of the supervisory regulations, the pension funds prefer high funding ratio over low funding ratio. While looking at improving the funding ratio, the funding ratio should be monitored for possible adverse developments. Undesired risks can also be dealt with by hedging the risks with financial instruments available in the market.

ASSETS	LIABILITIES
Investments	**Liabilities**
Stocks	Pensions
Bonds	
Alternative Investments	
Hedge Portfolio	
Options	
Swaps	
Swaptions	

figure 1. **Balance sheet of a typical pension fund** - Asset side of the balance sheet consists of core investments and hedge portfolio, the liability side is the present value of all present and future pensions payments. Core investments refer to the investments in stocks, bonds and alternative investments. The hedge portfolio consists of options, swaps, swaptions etc.

A high level balance sheet of a pension fund is given in *figure 1.* The assets are the investments, the liabilities are the future pension benefit payments. Valuing liquid investments in financial instruments is usually as straightforward as looking up the asset prices in the financial markets and summing these values up to the total asset value. The valuation of illiquid assets is more complicated, but is not the subject of this thesis. As the liabilities are not traded in the market, the value of the liabilities cannot be found from the markets but should be assessed at fair value. This means that future pension payments should be valued by discounting the nominal amounts of expected future pension payments based on the nominal yield curve (Engel, Kat and Kocken September 2005). By means of this mechanism, fluctuating interest rates cause the present value of the liabilities to fluctuate over time. An increasing yield curve will decrease the present value of the liabilities, while a decreasing yield curve increases the present value of the liabilities. As the funding ratio is defined as the total assets over total liabilities, decreasing interest rates (ceteris paribus) damage the funding ratio.

2.2 Involved derivatives and terminologies

To have a good understanding of this research, a couple of elements should be made clear.

2.2.1 Swaps

"An agreement to exchange cash flows in the future according to a prearranged formula" is the definition used by Hull (Hull 2009). In practice, two counterparties agree to exchange fixed interest rate payments for floating interest rate payments over a notional without exchanging the notional itself. The floating rate is a short term market interest rate, for example the 6-month LIBOR (London InterBank Offer Rate). The fixed interest rate is chosen such that the expected value of all floating payments is equal to the value of all fixed payments. So at initiation, the swap contract is priced at 0 for both counterparties. No counterparty needs to pay a premium to the other counterparty. The payer of the fixed rate has entered the so-called payer swap, while the receiver of the fixed rate has entered the so-called receiver swap. The swap value has a *linear* relationship (convexity effects ignored) with the underlying interest rate corresponding to the maturity of the swap. If the underlying interest rate increases, the receiver swap will lose value, while the value goes up if the interest rate goes down.

2.2.2 Swaptions

A swaption is a right to enter into a swap contract at a predefined date in the future. The contract specifies the strike level, the expiration date, the maturity of the underlying swap contract, the notional and whether it gives the right to enter a receiver swap or a payer swap. As the swaption is an option, at expiration the option holder has the right, but not the obligation, to enter into the underlying swap contract. The holder will exercise this right, if the swaption matures in the money. If the swaption matures out of the money, entering the swap in the market is possible at better conditions. As an illustration: an out of the money receiver swaption might give the right to receive a fixed rate of 4% in exchange for floating, while in the market a swap can be entered at no additional costs where those same floating payments are exchanged for a fixed rate higher than 4%. The option feature of the swaption can provide insurance against adverse movements of the underlying interest rate, while the upside potential is retained. When a swaption contract is entered, the buyer has to pay a premium.

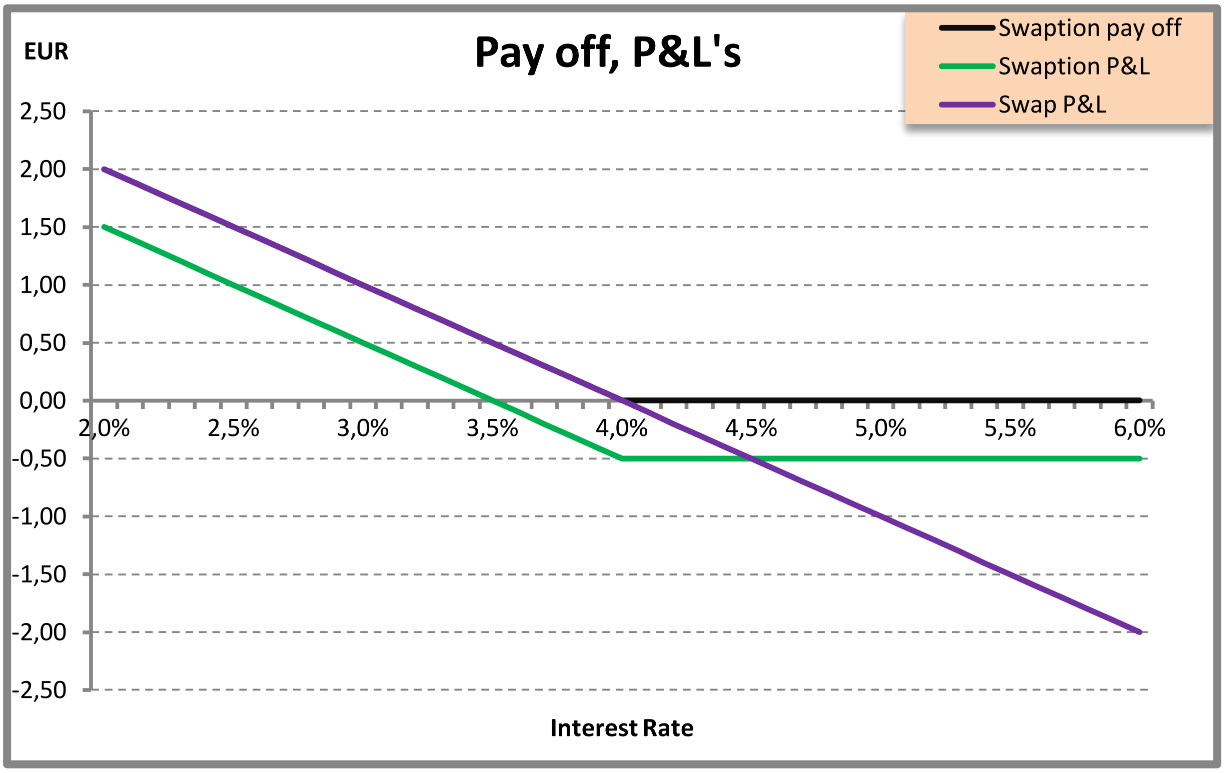

figure 2. **Stylized pay off and P&L of swaption and swap** – The graph shows the value development of different instruments for different levels of the interest rate. The swap P&L has linear pay off, the swaption P&L has non linear pay off. As the swaption P&L is the difference between the swaption pay off and the initial premium, the swaption P&L line is shifted down from the swaption pay off line.

The value of a swaption contract has a *non linear* relationship with the underlying interest rate. The swaption becomes less sensitive to changes of the underlying interest rate when the swaption becomes out the money. The swaption value becomes more sensitive to changes of the underlying interest rate when the swaption gets more in the money. Stylized pay off diagrams and P&L graphs for both a receiver swap and a receiver swaption is given in *figure 2*. The swap pay off is given by the straight purple line. The receiver swaption has a positive pay off if it expires in the money. That is the case if the interest rate decreases. In case the interest rate increases, the receiver swaption matures out the money and has no pay off (black line, which is overlapped by the purple line for in the money expiring swaptions). The P&L diagram of the swaption is shifted down from the pay off diagram of the swaptions due to the initial premium costs (green line). In the example used in *figure 2*, the strike is set at 4.00% and it can be seen that a decrease of about 0.50% (4.00% minus 3.50%) is needed to break even.

2.3 Hedging liabilities

To mitigate the effects of decreasing interest rates on the liabilities, the pension fund can construct a hedge portfolio. In that case, decreasing interest rates will still increase the liability side of the balance sheet, but this interest rate move increases the value of the hedge portfolio on the asset side of the balance sheet as well. If the hedge portfolio is constructed correctly, the asset side of the balance sheet will increase as much as the liability side does. Assuming the funding ratio at initiation to be equal to 100%, the funding ratio will stay constant. The hedge portfolio should gain value when the yield curve goes down. The instruments which give this pay off pattern is the receiver swap and the receiver swaption. Depending on the specific risk preference and financial situation of the pension fund, either swaps or swaptions (or a combination thereof) can be the appropriate hedging strategy. This choice is usually a strategic choice made by the board of the pension fund, but is not the issue at stake in this thesis. Rather, the focus is on the most efficient way to use swaptions as a hedge, once this choice is made.

In this research the possible use of swaptions as a hedge is investigated. Obviously, keeping the upside potential, while hedging the risks is preferred. However, the premium paid for the swaption is still seen as a drawback of the strategy. The profitability of a swaption contract strongly depends on the swaption premium paid. Earlier research on option premium on the S&P 500 index options by Bakshi (Bakshi G. 2003) showed that the implied volatility tends to overestimate the realized volatility. De Jong et al (De Jong F.C.J.M. 2004) showed similar discrepancy in the US swaption markets. Fornari et al (Fornari 2005) argue that the implied volatility over estimates the expected volatility as a compensation for the volatility risk. This phenomenon is stronger for the short maturity swaptions and the difference increases in high volatile periods. As the swaption markets in Europe might suffer from the same inefficiencies, swaption prices might be too expensive. PGGM found reason in this to investigate alternatives for the swaption strategy. Ideally, the alternative should have a pay off pattern similar to the swaption contract, but realize this pay off pattern at lower expected costs. This might be possible when the swaption is replicated by a dynamic delta replicating strategy (DDRS).

2.4 Delta and delta replication

The value of a swaption in life differs from the value of a swaption at expiration. As long as the swaption is in life, the swaption has time value. The black curve in *figure 3* gives a possible in life swaption value relationship for various interest rates. For a given swaption, the difference between the swaption value in life and the intrinsic swaption value depends on the IV, the moneyness of the swaption and the time to maturity of the specific swaption contract. The intrinsic value of the swaption is defined as the swaption pay off if the swaption could be exercised immediately at a given date.

To explain deltas, we need to focus ourselves on the swaptions in life. As can be seen in *figure 3*, the swaption has a *non linear* development of value during its lifetime. The change of swaption value during its lifetime and swap value can be calculated for small (parallel) shifts of the underlying yield curve. The delta of the swaption is the value change of the swaption relative to the value change of the underlying swap. For example, if the swaption gains EUR 70 in value for a given interest rate change while the underlying swap gains EUR 100 in value, the delta is 70% (=70/100).

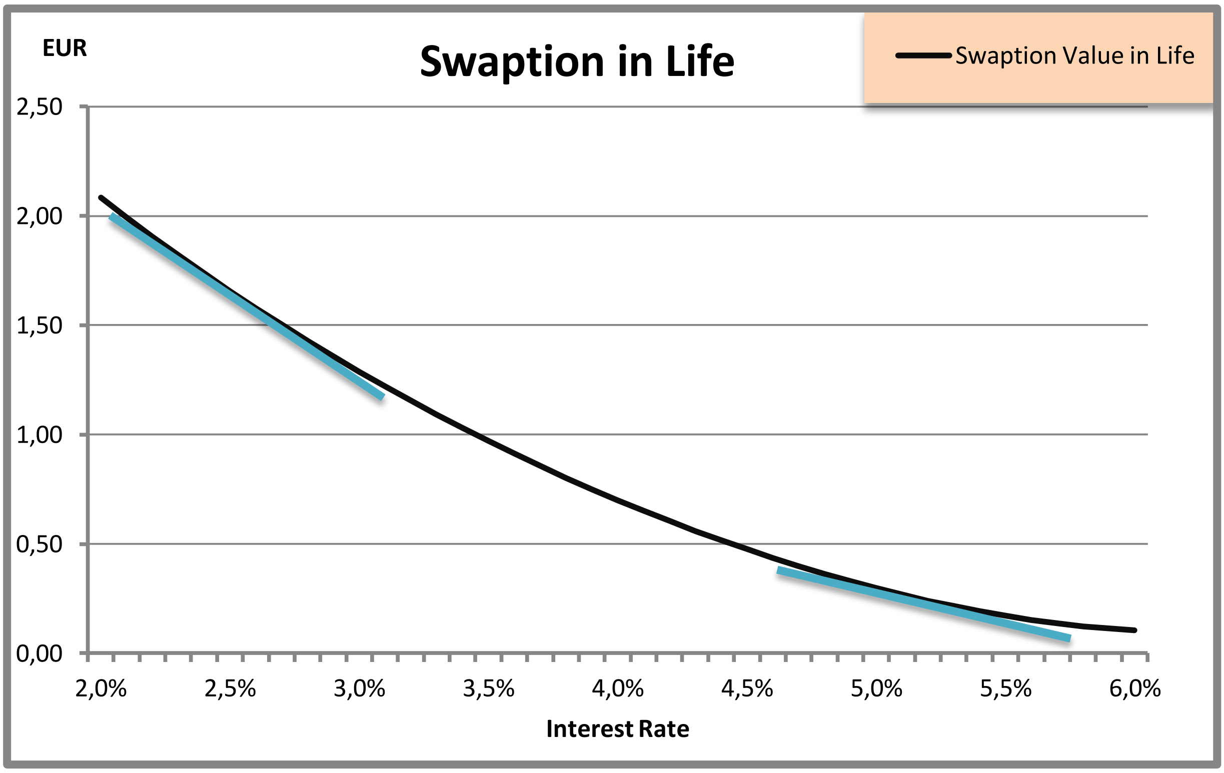

***figure 3.* Swaption value in life –** The swaption value in life has non linear relationship with the underlying interest rate. Out the money swaptions are less sensitive for interest changes, in the money swaption are more sensitive. This can be seen by the slope of the curve.

The delta of the swaption is given by the slope in *figure 3*. The delta of the swaption is an indication for the probability of the swaption expiring in the money. A delta equal to 70% can be interpreted as the swaption having a probability of 70% to expire in the money. At the money (ATM) swaptions have a probability of about 50% to expire in the money (ITM) and about 50% probability to expire out of the money (OTM). As soon as the swaption gets ITM, the delta grows, meaning that the probability expiring ITM is increased. For the OTM swaptions, the opposite holds.

The delta provides information about the hedge ratio as well. The delta can be translated easily to what portion of the notional is protected by the swaption. The higher the swaption delta is, the higher protection the swaption provides for the liabilities.

The described *non linear* relationship of swaptions with the underlying interest rate means that the hedge ratio is continuously updated through the swaption lifetime. As the subject of this thesis is focused on the swaption strategy versus the DDRS, this is an important feature for the model which is created to simulate both strategies. To replicate the swaption by the DDRS, the swap portfolio has to be rebalanced such that the deltas are equalized to the swaption deltas at any particular moment in time. As the swaption deltas change continuously, perfect replication implies continuous updating of the swap portfolio in the DDRS. In practice, perfect replication is not possible. Instead of continuous rebalancing, discrete rebalancing is used.

For the DDRS, the swap notional has to be increased as the swaption gets more ITM. The swap notional has to be eliminated when the reverse happens. Repeating this strategy over and over again is accompanied by incurring costs. These costs can be categorized into different sources:

- Buy high, sell low
- Trading costs
- Hedging error
    - Discrete rebalancing when replicating swaptions (*non linear* instrument)
    - Model errors

<u>Buy high, sell low</u>

When the underlying interest rate moves up and down, in the DDRS swap positions have to be build up and reduced again. Building up the swap positions happens when the swap value is high. Eliminating swap positions happens when the swap value has decreased compared to the previous rebalancing level. This trading pattern result in a loss.

<u>Trading costs</u>

Trading in the financial markets is performed at a cost. The costs for trading swap is due to the bid-offer spread in the market. When the swap is bought, the higher offer price has to be paid. To sell the swap, one has to trade at the lower bid price. Any trade therefore occurs at initial trading costs.

Hedging error

According Coleman *et al* (Thomas F. Coleman 1999), the hedging error may have two reasons. First reason is the discrete rebalancing in the DDRS. Second reason is the possible model errors.

Discrete rebalancing

Due to discrete rebalancing by the DDRS, the hedge in the DDRS is not perfectly replicating the swaption hedge. The DDRS delta has to be adjusted to the swaption delta at once after the swaption delta has changed gradually to a particular level. Because the DDRS is always late in adjusting delta to the appropriate level every time, the DDRS portfolio value changes at a different pace than the swaption strategy. The relative loss of the DDRS is called the hedging error.

Model error

The swaption valuation model might contain errors. In the case of the swaption valuation model, this would mean the error in describing the delta of the swaption.

1. Jumps: As the condition of perfect delta replication is the gradual change of the swaption delta, any disturbance of this property will cause hedging errors. If the development of the interest rate is characterized by jumps, the gradual development of the delta is violated.
2. Volatility: Stochastic volatility causes model error as well. As the move of the implied volatility has effects on the swaption value and delta, any unexpected move of the IV will lead to change in the swaption value and the swaption delta. As the swaps only hedge the deltas of a swaption, discrepancy will raise between the swaption value and the dynamic hedge portfolio.

Trading costs and hedging errors are related to each other as both are dependent on the rebalancing frequency. Higher rebalancing frequency leads to higher trading costs, but lower hedging error. Lower rebalancing frequency leads to lower trading costs and higher hedging error. In optimizing the DDRS with respect to the rebalancing frequency, there is a tradeoff between the trading costs and the hedging error.

2.5 Research question

In this thesis two different hedge strategies will be investigated.

- Buy and hold swaption strategy
- Dynamic Delta Replication Strategy

Using the results, the research question of my thesis will be answered. The research question is: "Which of the swaption strategy or Dynamic Delta Replication Strategy is more efficient to fulfill the liability hedge needs of pension funds?" Both ways of hedging will be simulated by back testing with historical data to figure out which alternative was more efficient in historical context.

Theoretically, the DDRS should yield the same return distribution as the swaption strategy. However, due to the mentioned costs and rebalancing errors, this might not be the case in practice. PGGM wants to perform a research to find out which strategy is more efficient and applicable in practice. In this research the premium paid for the swaption is compared to the total costs of the DDRS. In the most favorable scenario for the DDRS, PGGM can save as much money as the swaption premium. In the worst scenario the swaption can perform many times better than the DDRS.

3 Data

For this research, data from different sources has been gathered due to impossibility to get all needed data from one source. Available data from different sources has been cross-checked to be sure about the general development of different variables.

Essential data are the interest rates for different maturities to constitute the Term Structure of Interest Rates (TSI). As the swap rates are not available for the needed maturities, zero rates have been downloaded from DataStream (DataStream). Using the zero TSI, swap rates can be calculated. As the zero rates are constituted from bond prices in the market, zero rates for some data points may be interpolated and even extrapolated for long maturities. The TSI and the IV are needed to calculate swaption values. The IV data has been downloaded from Bloomberg (Bloomberg).

3.1 Interest rates

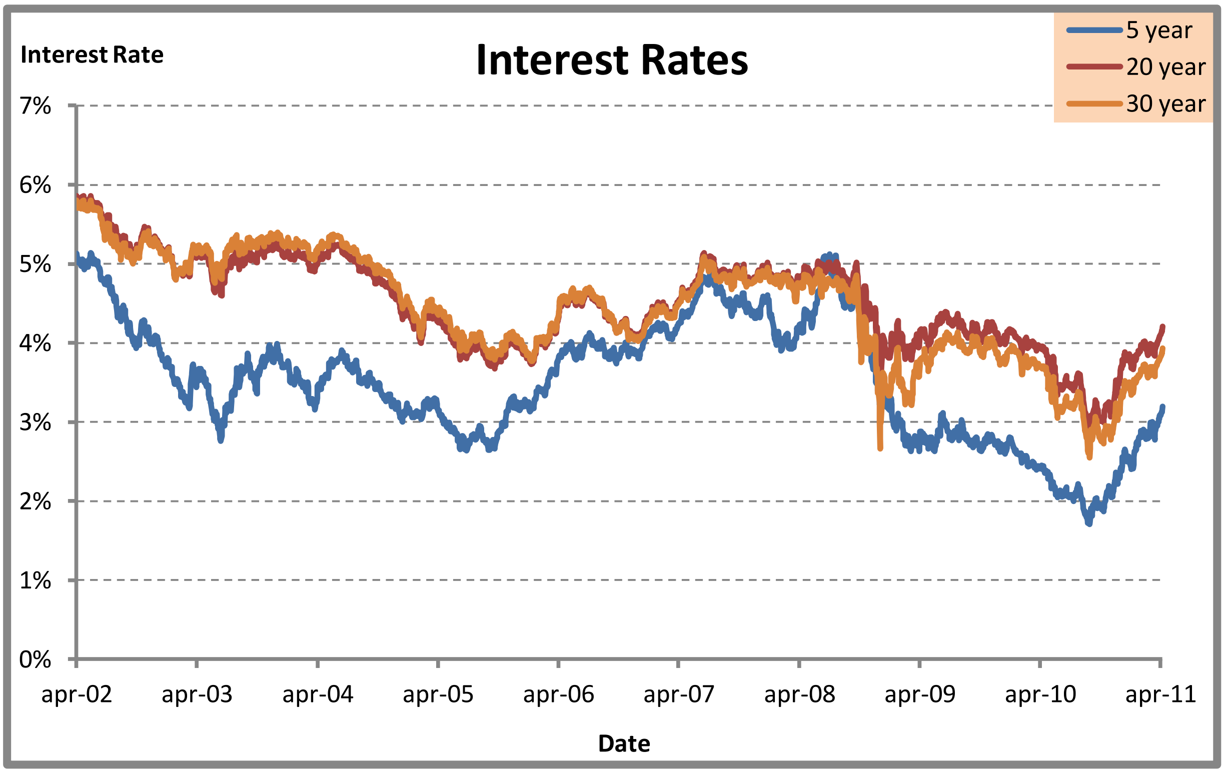

figure 4. **Interest rates –** Development of the interest rate for different maturities is shown in the figure. The graph shows the development from April 2002 until April 2011.

Figure 4 shows the development of the zero interest rates for different maturities. While the 30 years zero yielded 5.8% in 2002, in the crisis period (December 2008) the interest rate was declined to 2.66%. In April 2011, the 30 years yield was back at 3.8%.

This suggest that overall the receiver swaps have had positive return in this period. As the swaption value increases due to drop of the interest rates, the swaptions will have positive pay off on average. If the decrease of the interest rate is sufficient to make up for the initial swaption premium, the swaptions will have a positive return on average. During the presentation of the empirical results, this expectation will be verified.

3.2 Term structure of interest rates

The interest rate data includes time series from April 2nd, 2002 until April 8th, 2011 and consist out of monthly maturities up to 35 years. Each term structure therefore consists of 420 data points (35 years times 12 months). To get interest rates for maturities in between the available monthly points, a simple *linear* interpolation method is used.

Figure 5 shows the TSI at different points in time. For the shorter maturities, the TSI shows upward slope. At the long maturities the interest rates tend to decrease.

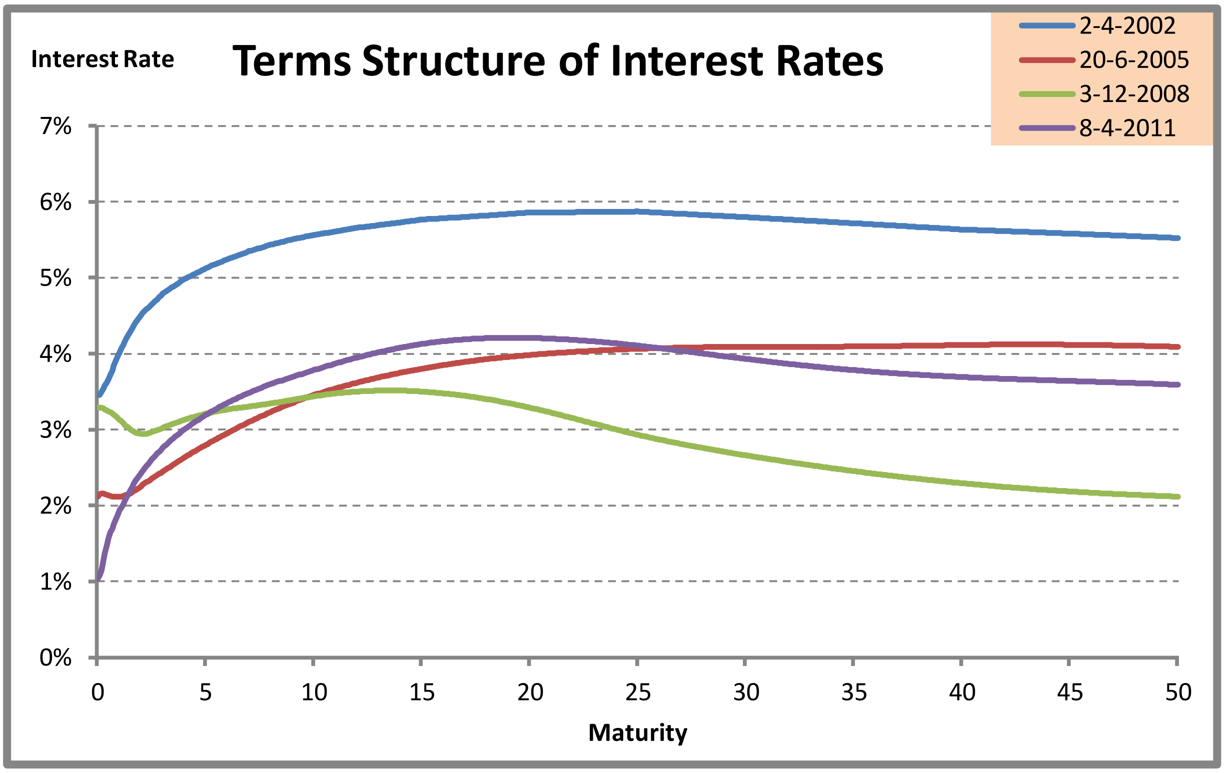

figure 5. **Term structure of interest rates -** The graph shows the term structure of zero interest rates at various dates.

3.3 Volatility

3.3.1 Realized volatility

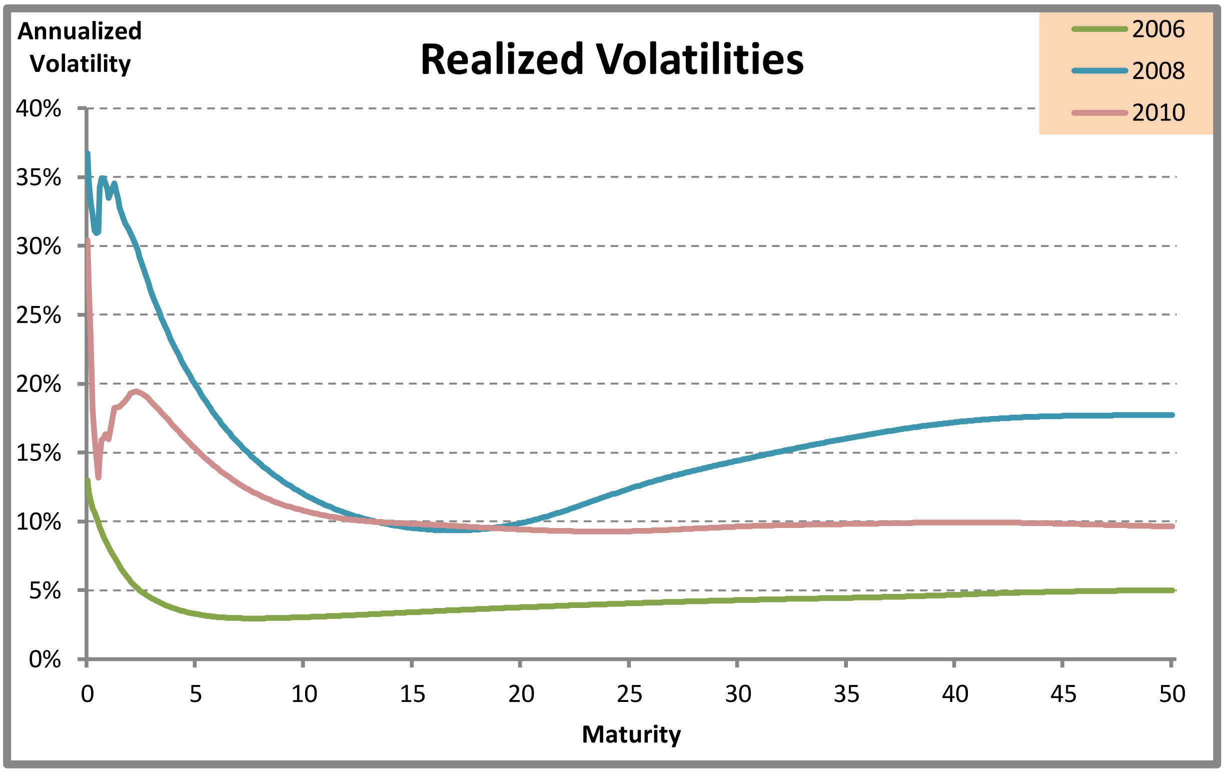

figure 6. **Realized interest rate volatility –** Realized interest rate volatilities for different maturities in different periods is given by the graph.

Because the interest rates are changing through time, the TSI faces volatility. Due to the mean reversion property of the interest rates, the longer maturity interest rates are less volatile than the short maturity interest rates (Shiller 1979)[1]. See *figure 6* for the realized volatility of different interest rate maturities in three different periods. In contrast to "normal times", the crisis year 2008 is characterized by higher volatility of the interest rates for the majority of the maturities. While in normal times the volatility was low for longer maturities, during the crisis the longer maturity volatility increased gradually.

3.3.2 Implied volatility

As the realized volatility can be measured afterwards, the swaption prices are based on the supply demand intersection point of swaptions. The volatility which leads to the swaption price in the market is called the implied volatility. The development of the IV for different maturities is shown in

[1] As the interest rates for longer horizons are better predictors of the long term average interest rates, the volatility of these rates are lower compared to the short term interest rates.

figure 7. The IV depends on the maturity of the swaption. The long maturity swaption are based on lower IV. For the total research period, ATM IVs in time series format was found.

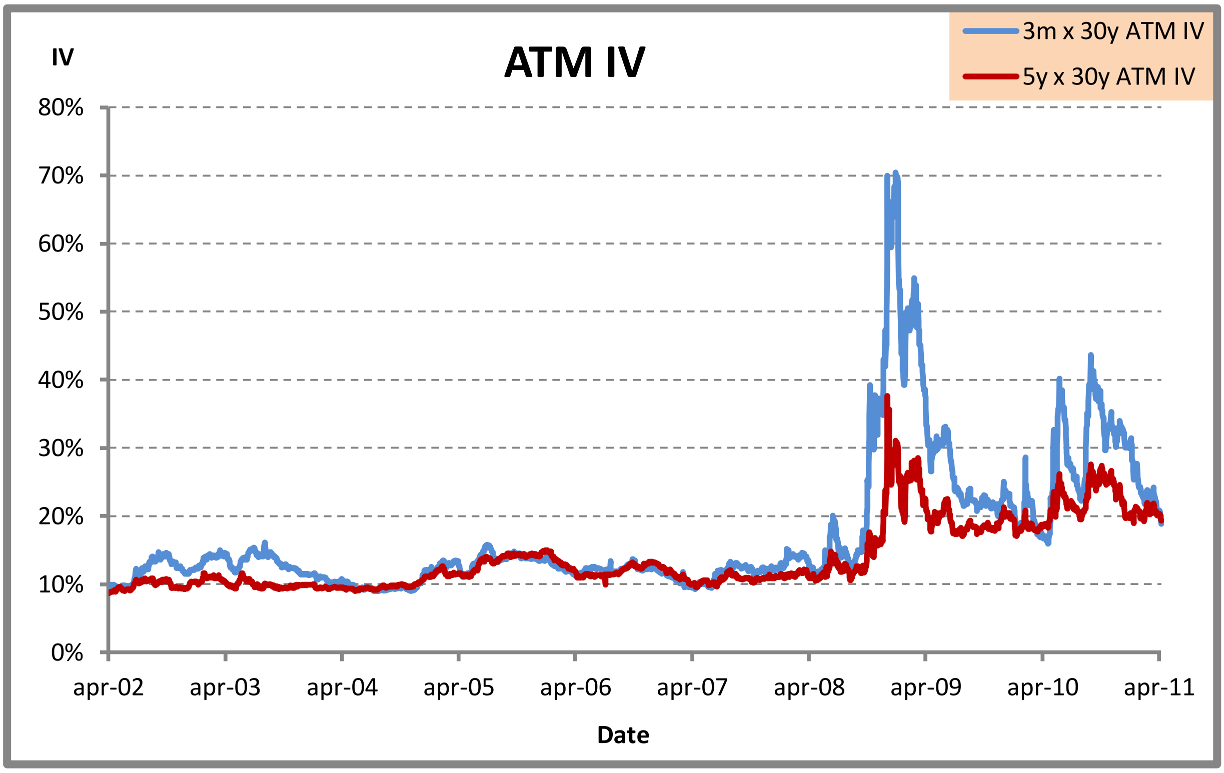

figure 7. **Swaption ATM IV development** - The graph shows the development of the implied volatilities for two different option maturities. The time frame is April 2nd, 2002 until April 8th, 2011.

3.3.2.1 Out of the money implied volatility

Figure 7 shows the development of the ATM IV[2]. As the simulation model needs valuation of OTM swaptions, OTM IVs are needed. To calculate the OTM IVs in the model, OTM IV data from JP Morgan (JPMorgan) was used. This data is available in time series for OTM levels -100, -50, +50, +100 bps.

In *figure 8* the development of the IV for different moneyness is shown for 2 years swaptions on 30 year swaps. The spread between the OTM IVs and the ATM IVs fluctuates over time. As suggested by Coleman et al. (Thomas F. Coleman 1999), the IV depends on both the moneyness and the maturity of the swaption.

[2] The normalized IV develops more stable compared to the given IV. The normalized IV is calculated by the multiplication of the given IV and the swap rate. As the interest rate and the IV are negatively correlated, the normalized IV is affected by two opposing effects for any development in the market.

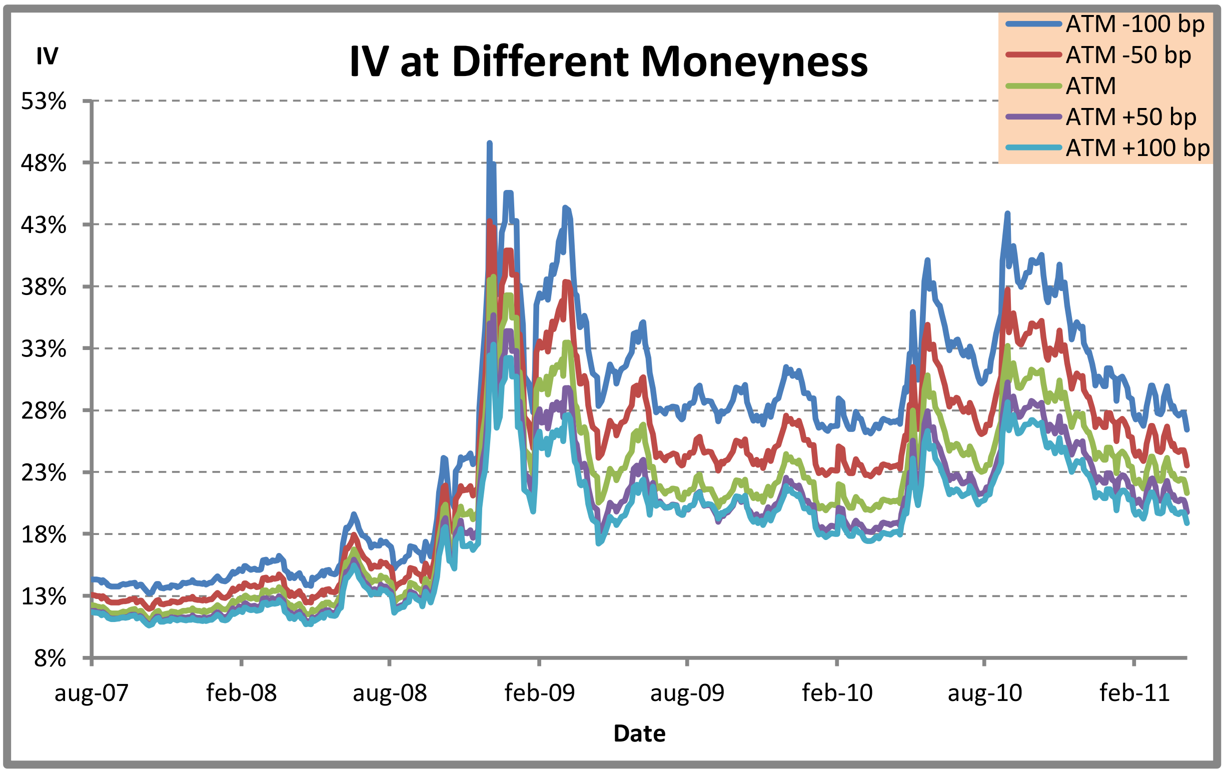

figure 8. **IV at different moneyness for 2y x 30y swaptions -** The development of the out the money implied volatilities in the period August 2007 until February 2011 is given in this graph. The IV spread for different moneyness increased during the financial crisis.

The spread between the ATM IV and both OTM IVs is shown in *figure 9*. The positive spread means that the OTM IV is higher than the ATM IV. The negative spread means that the OTM IV is lower than the ATM IV. The absolute value of the spread between ATM IV and the OTM IV (ATM -100 bps) is clearly higher compared to the absolute value of the spread between ATM IV and the OTM IV (ATM +100 bps). The bigger deviation of the ATM -100 bps compared to ATM +100 bps shows the convexity of the IV for different moneyness. This means that in the swaption markets a volatility skew is observed. The spread for OTM IVs tend to increase in uncertain times. Combining the increase of the ATM IVs due to uncertainty in the market, the OTM IVs grew rapidly to extremely high levels in the crisis.

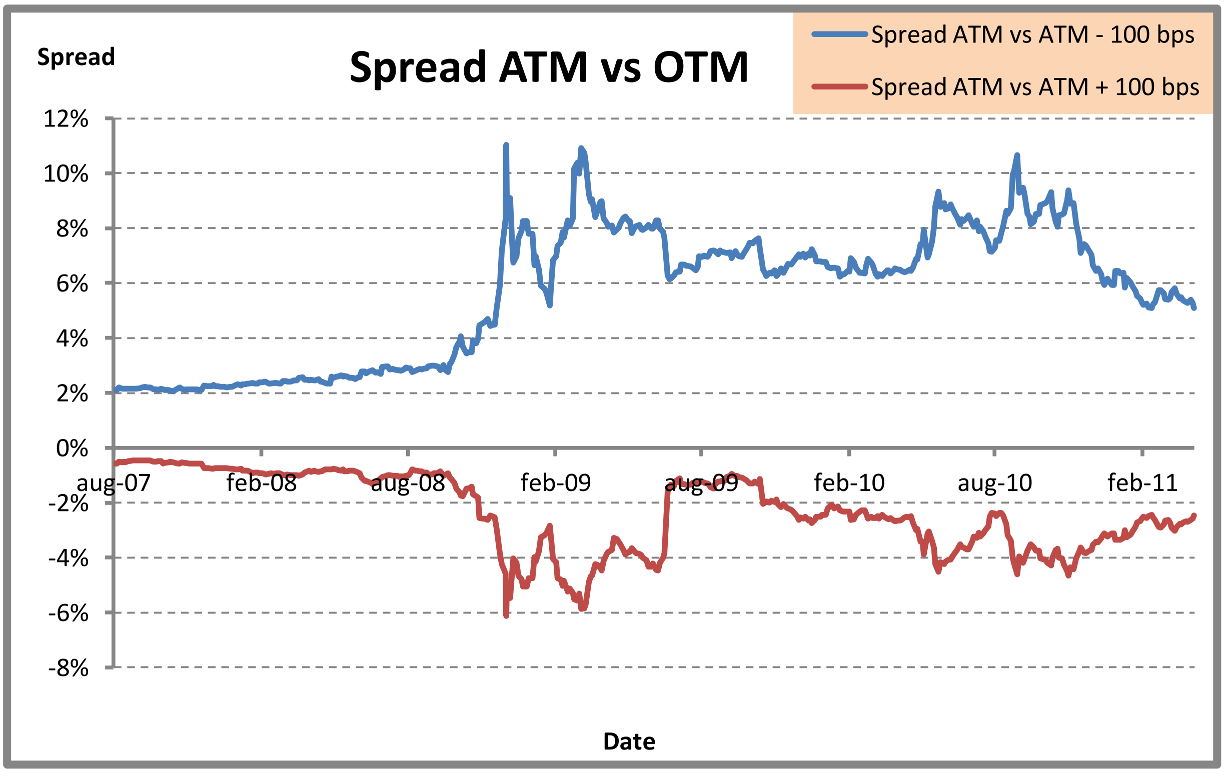

figure 9. **Spread ATM versus OTM for 2y x 30y swaptions -** The development of the difference between the ATM and the OTM IVs are given in the figure from August 2007 until February 2011. The deviations fluctuate over time. The IV spread for different moneyness increased during the financial crisis.

3.3.3 Swaption premium

As the IV is one of the input parameters of the swaption valuation formula, fluctuating IV through time affects the level of the swaption premium as well. For different maturities, the development of the swaption premium is shown in *figure 10*. As the return of the swaption depends strongly on the swaption premium paid at upfront[3], the swaption premium might have substantial effect on the difference between the swaption and the DDRS returns. The given graph is relevant for my further analysis of swaption strategy versus the DDRS.

[3] The swaption premium is paid at upfront. However, nowadays this convention in the market is changing to payment at expiration.

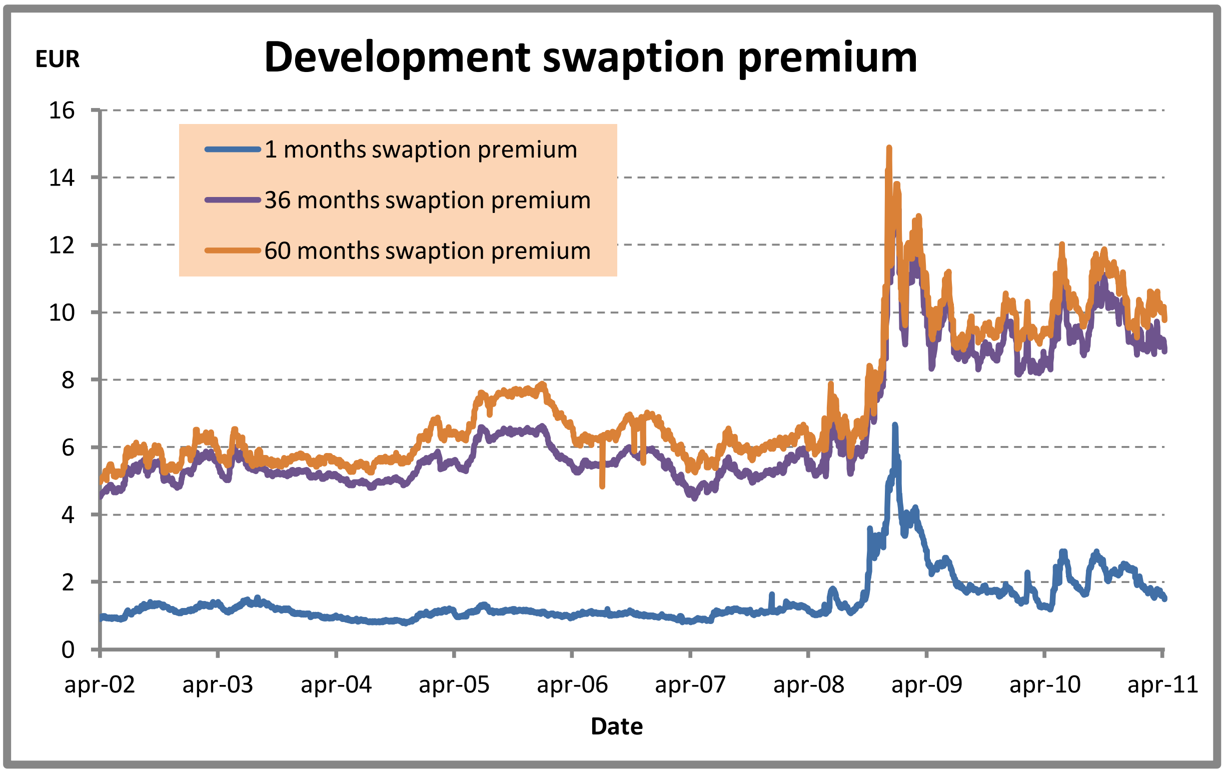

figure 10. **Development swaption premiums for 3 different maturities** - The development of the swaption premium between April 2002 and April 2011 is given in the graph. The figure shows the increase of the swaption premium during the crisis at all maturities.

3.3.3.1 Implied volatility versus realized volatility

As the swaption premium in the market implies a volatility which might not be equal to the future volatility, market failures may exist which prevent to price the swaptions correctly. A comparison of the implied volatility and the realized volatility provides information about the relative efficiency of the swaption strategy compared to the DDRS. If the realized volatility of the swap rate is equal to the implied volatility, the swaption was priced correctly. If this condition is not met, the swaption is overpriced (IV>RV) or underpriced (IV<RV). Of course, for any given swaption, we expect the two to differ. It is however particularly interesting to see whether the implied volatility is consistently higher or lower than the realized volatility.

The graphical comparison of the one year normalized swaption implied volatility and realized volatility is shown in *figure 11*. At each date, the figure shows the realized volatility over the next year, to make it comparable with the implied volatility at the same date. As can be seen from the figure, the implied volatility was a good estimate of the realized volatility until January 2008. From that moment on, a discrepancy between the volatilities became apparent. As the realized volatility in the figure looks one year ahead, the realized volatility shot up due to the interest rate crash around December 2008. The implied volatility however, followed a similar increase after one year. In the period that the implied volatility was lower than the realized volatility (during 2008), the swaptions were underpriced. The logical consequence is that in this period the swaption strategy performed better compared to the DDRS. In the period after (January 2009 – April 2010) the inverse is observed, the implied volatility overtook the realized volatility. This suggest that the swaption premium is too high and the DDRS is likely to be more efficient. Overall, it seems that implied volatilities are a reaction to what is recently observed in the market, instead of being a true predictor of volatility to come.

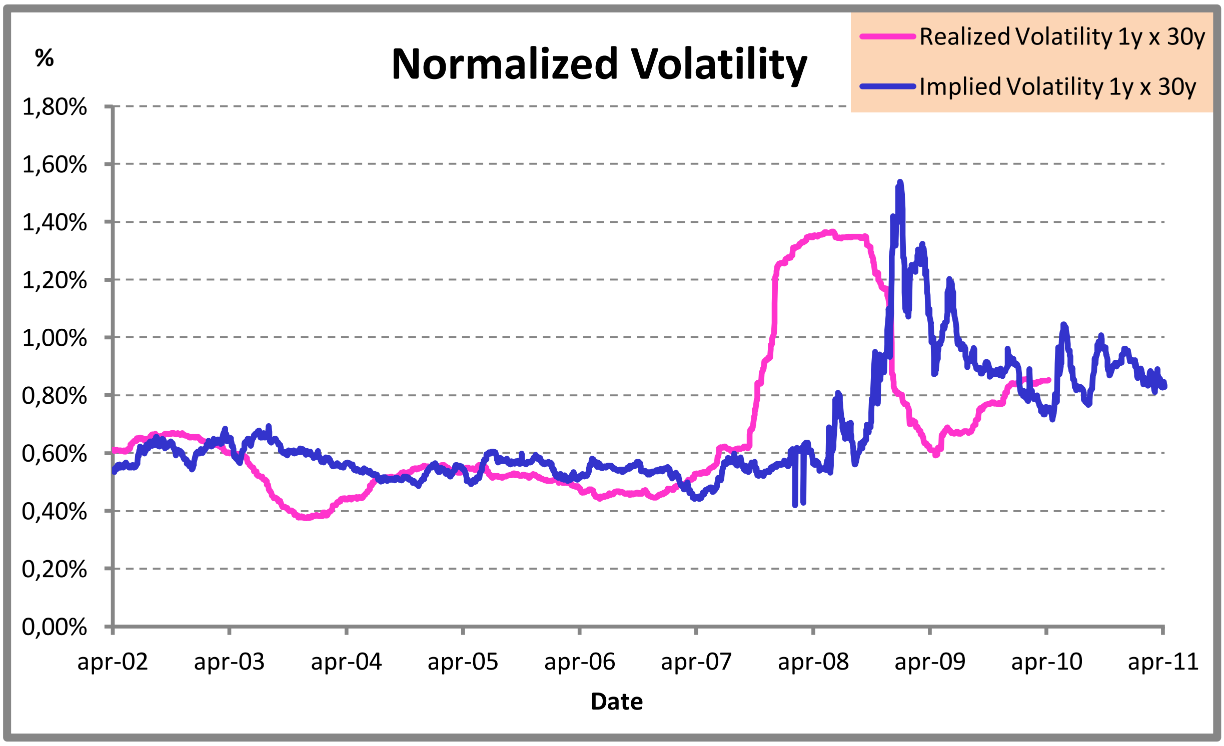

figure 11. **Normalized implied volatility versus normalized realized volatility** – The one year swaption implied volatility (blue line) is compared with the realized volatility (purple line). The implied volatility showed comparable development as the realized volatility until 2008. After January 2008, discrepancies raised. As the realized volatility is looking forward, it increased prior to the implied volatility. The normalized implied volatility is the result of the implied volatility multiplied by the interest rate. Therefore the scale of the y-axis is different than figure 7 and figure 8.

In addition to the one year swaption volatilities, the five years swaption volatilities are compared in *figure 12*. Due to limited availability of the interest rates, realized volatility has been calculated for swaptions starting until April 2006. The crisis period is captured by five years swaptions which are initiated between January 2004 and December 2008, so the realized volatilities were affected by the crisis in 2008.

The implied volatility accompanied the realized volatility until January 2004. In the period after January 2004, the realized volatility figure captures the crisis period and shows an increase due to the crash, while the implied volatility develops more moderate. In this situation the swaptions are relatively cheap and the swaption is expected to be more efficient than the DDRS.

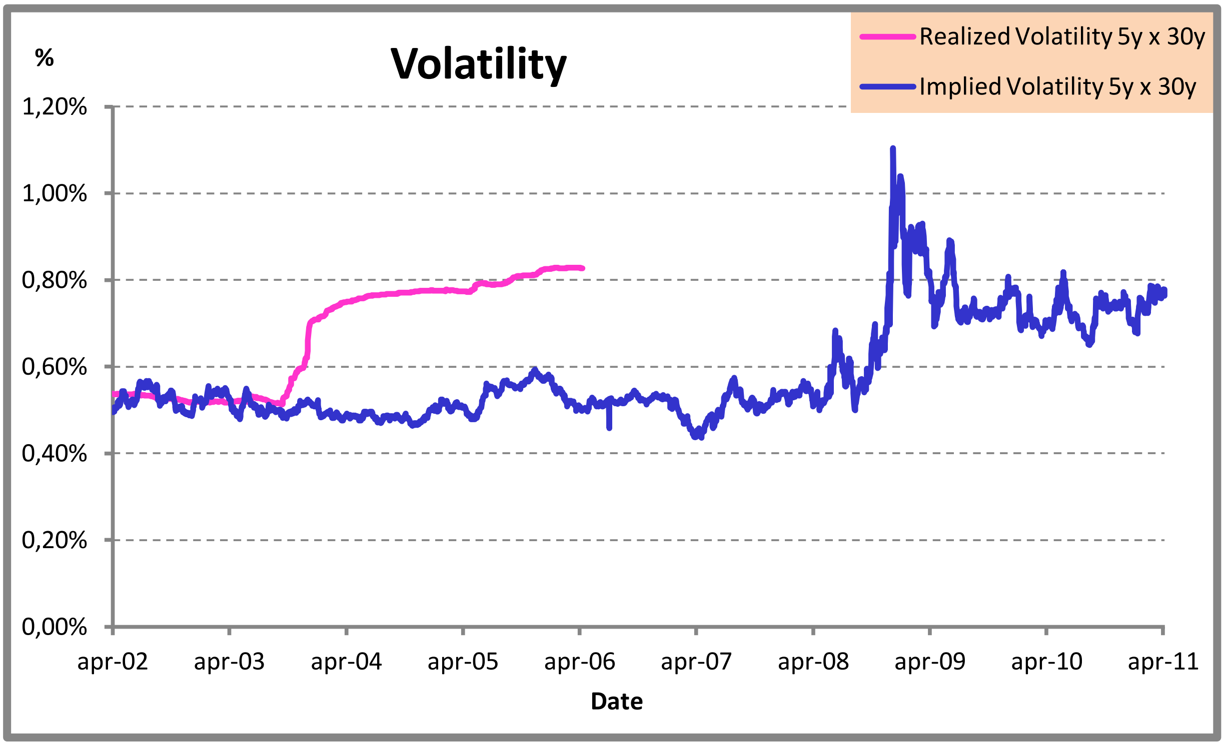

figure 12. **Normalized implied volatility versus normalized realized volatility** – The five year swaption implied volatility (blue line) is compared with the realized volatility (purple line). The implied volatility shows comparable development as the realized volatility until January 2004. After January 2004, discrepancies raised. As the realized volatility is looking forward, it increased prior to the implied volatility. The normalized implied volatility is the result of the implied volatility multiplied by the interest rate. Therefore the scale of the y-axis is different than figure 7 and figure 8.

3.4 Estimated data

In order to estimate the IV for every possible combination of moneyness and maturity, the IV has been modeled by using the available data for different maturities and moneyness. To summarize, the ATM IVs are available in time series. Besides that, the OTM IVs for moneyness -100, -50, +50, +100 basis points are available in time series for a shorter period. The IV for different moneyness and maturity is plotted in *figure 13*. The graph is a snapshot of the IV surface on December 3rd, 2008. This graph shows the volatility skew for different maturities. At all maturities the IV shows an inverse relationship between the moneyness and the IV. The graph includes the values given in *table 1*.

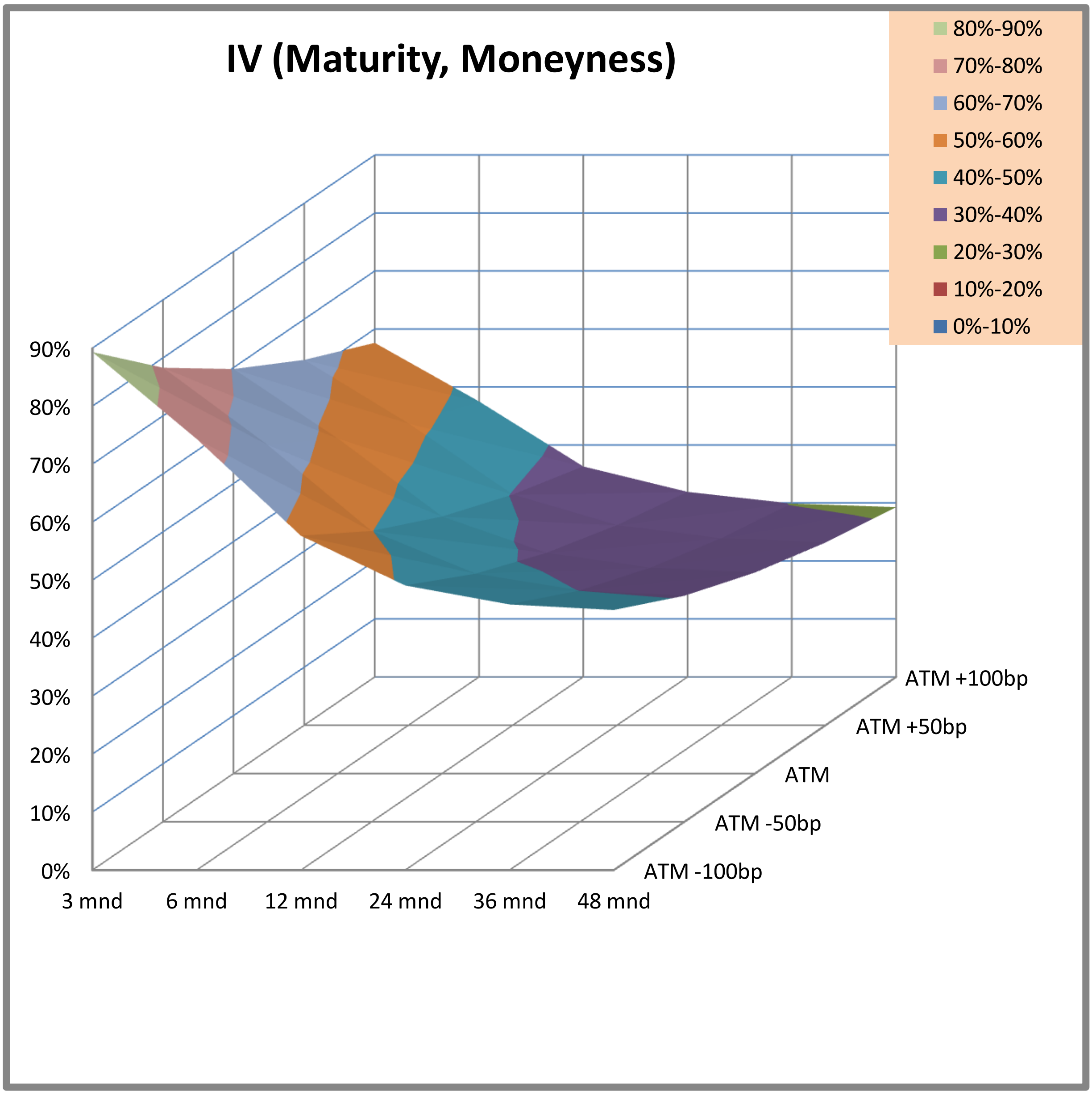

***figure 13.* Volatility surface for different maturities and moneyness at December 3rd, 2008 –** IV levels for different moneyness and different maturities are given in the graph. Different IV level brackets are represented by different colors.

	ATM - 100 bps	ATM + 100 bps
High maturity	45%	29%
Low maturity	89%	58%

***table 1.* IV levels at corner points –** Values of the corner points of figure 13 are given in the table.

The higher IV for swaptions at the downside shows that the market expects a higher probability of occurrence of lower swap rates compared to the log-normal distribution. Besides the moneyness, the maturity matters as well. The shorter maturities have relatively higher IV[4]. These relationships hold at a different magnitude for the realized volatilities as well.

The described relationship is used to create an IV model. At the first stage of this model the volatility for a particular moneyness is estimated for different maturities given the relationship with the ATM IV. In the second stage the IV is calculated for the right maturity by interpolating between different maturities. The resulting IV is used in the swaption valuation model.

3.5 Simulation variables

Before the simulations of swaptions and the DDRS can be performed, a couple of parameters have to be set. Simulations with slightly different parameters will make it possible to perform a sensitivity analysis. This paragraph contains the explanation and motivation of the next parameters:

- Moneyness swaption
- Swaption maturities (option part & swap part)
- Start date simulations
- Market spreads (swap market and swaption market spreads)
- Rebalancing period for the DDRS

<u>Moneyness</u>

The moneyness of the swaptions at inception is set to ATM swaptions. The delta of both in the money and out of the money swaptions are less sensitive to interest rate changes and are therefore likely to underestimate the differences between the swaption strategy and the DDRS.

<u>Swaption maturities</u>

1) <u>Swap maturity</u>

In practice, pension liabilities have long duration. This is reflected by setting the swap maturity to 30 years.

2) <u>Option maturity</u>

Option maturities from one month to 60 months have been chosen. As the swaptions with longer maturities have low liquidity, these options are not appropriate. Different option maturities will provide insight in different time decay and gamma effect of the different maturity options which may

[4] For normalized IV this holds for a smaller extent.

have a substantial effect on my analysis. The Vega effects (the sensitivity of the swaption value for changes in the IV) for different maturities might vary as well.

<u>Start date simulations</u>

Within the period between April 2nd, 2002 until April 8th, 2011, one simulation is initiated every month. As the first day of the data set is the 2nd day of the months, all simulations start at the second day of each months. For some simulations the initiation dates moved to the third or fourth day of the month in case the second day of the month was not a business day. The same rule is applied for the expiration dates as well. By doing this, 4710 simulations are performed, 108 simulations for 1 month swaptions, 107 simulations for 2 months swaptions until 49 simulations for 60 months swaptions. The scheme for the start dates is shown in *figure 14*.

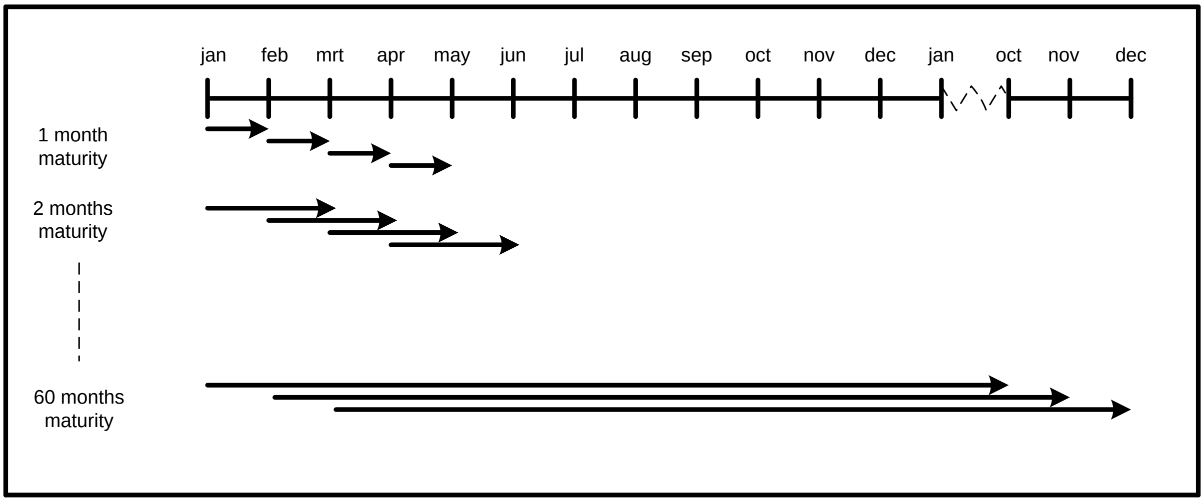

***figure 14.* Scheme executed simulations** – In the figure, the graphical representation of the simulations is given. One month maturities are simulated without any overlapping periods. The longer maturities have overlapping periods equal to maturity-1 months. The number of simulations decreased gradually for higher swaption maturities.

<u>Market spreads</u>

The swap trading cost is an important factor in my analysis. These costs are *linear* to the traded volumes (notional) and on the bid-offer spread in the swap market. The bid rate is the interest rate at which the market maker (counterparty of the pension fund) is prepared to buy swaps. The offer rate is the interest rate at which the market maker is willing to sell swaps. So, the pension fund is able to buy swaps immediately at the offer rate and sell at the bid rate[5]. The average of these rates is the

[5] Note that the quoted rates are for a specific or maximum notional, depending on market circumstances and the risk budget capacity of the market maker. For non-standard sized notional, other spreads are often appropriate.

mid rate and is often used to represent the prevailing market rate, even though this rate is actually not tradable. For example, the pension fund can buy receiver swaps for the fixed rate of 4.00%. In that case the pension fund will receive 4.00% fixed rate over the lifetime of the swap in exchange for paying the floating rate. The pension fund can sell the receiver swap at 4.01%. In that case the pension fund has to pay 4.01% fixed rate and receive floating. As the mid rate is 4.005%, the trading cost is equal to 0.005% (0.5 bps) times the notional. Buying at the offer or selling at the bid rate result in a loss for the pension fund. The trading costs are formulated as:

Trading costs[6] = ½ * bid-offer spread * notional * duration.

As the costs are *linear* to the swap market bid-offer spread, if the swap market bid-offer spread doubles, the total trading costs of the DDRS will double as well. In the DDRS, the pension fund has to execute these trades periodically at each rebalancing date. The sum of the incurred costs at each trade during a simulation constitutes the total trading costs of that particular simulation. In the simulation model, trading costs are parameterized for different values.

The swaption trading costs are parameterized in percentage points of IV. The spread in the swap market in basis points is translated into swaption market spread as percentage points of IV. As the swaption trading takes place once at the initiation, the spread in the swaption market affects the swaption trading costs only at initiation. The trading costs of swaptions have a *linear* relationship with the swaption market spread.

<u>Rebalancing period of the DDRS</u>

As the trading costs and hedging error is going to make the difference between swaption strategy and the DDRS, the variables regarding these costs have to be analyzed thoroughly. In this respect the frequency of the trades matter as well. The higher is the frequency of the swap trades, the higher is the trading costs of the DDRS, but the lower the hedging error will be. The total trading costs and the hedging error of the DDRS can be influenced by changing the rebalancing period of the swaps. To obtain a good insight into these effects, different rebalancing periods and trading costs will be simulated and analyzed.

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[6] The given relationship ignores discounting effects of the future trading costs. Hence the given formula is an approximation of the total trading costs of the DDRS.

3.6 Simulations explained

The research is performed to investigate whether the swaption strategy or the DDRS is more efficient. Depending on the situation different conclusions can be drawn. Especially the specific path of the underlying interest rate and the IV will probably have a big impact on the results. Besides that, the parameters used in the model will influence the results as well. To get widespread results, different parameters are varied and different combinations of parameters have been used to replicate swaptions with different maturities and different start dates in this research.

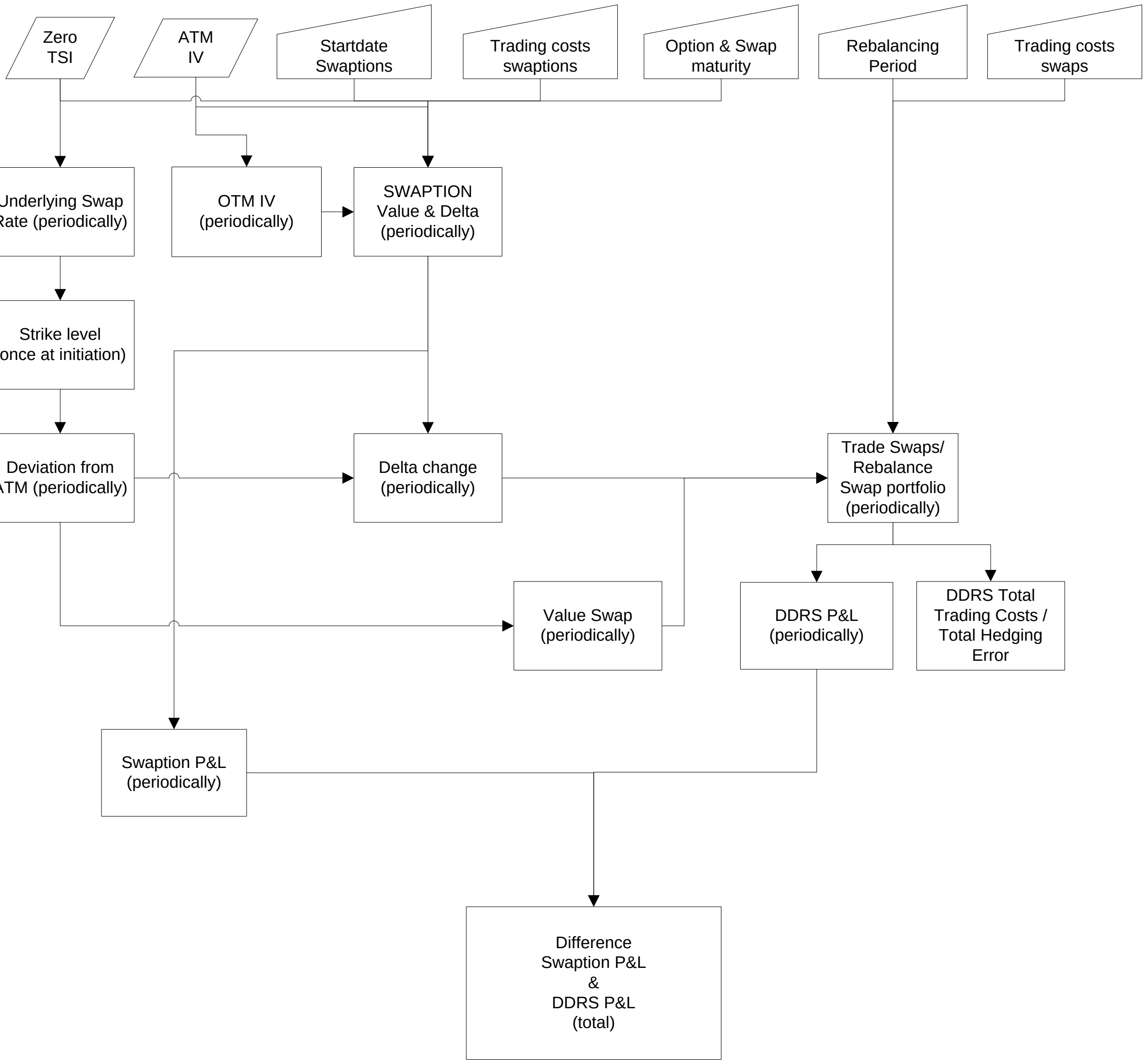

figure 15. **Flow chart simulations process –** The flow chart shows the needed data and the data channels to calculate the swaption P&L, delta development of the swaption, DDRS P&L, the trading costs and the hedging error of the DDRS. At the last stage, the difference between swaption P&L and the DDRS P&L is calculated.

For efficiency purposes I modeled the calculations in Matlab. *Figure 15* shows the flow chart of the model and calculations to get the final results. As can be seen in the figure, the zero rates and the IV is needed to calculate the swaption value, the swaption profit & loss (P&L) and swaption delta during the simulation. The delta is exported to the DDRS. In the DDRS, the periodical change of delta is used to rebalance the swap notional. The periodical change of the delta is also used to calculate the swap trading costs for that period. In the last stage of the model, the DDRS total P&L is calculated and subtracted from the swaption total P&L. This number is the end result of one simulation. A positive result indicates that the swaption strategy performed better over that specific time frame, while a negative result indicates a better performance of the DDRS.

3.7 Example simulation

In *table 2*, an example of the relevant output of a swaption and DDRS simulation is shown. The three months option on a 30 years swap has been purchased at September 3rd, 2008. The DDRS is rebalanced once a week, in total fourteen times within three months. In the column marked 'F' (forward rate), it can be seen that at initiation date the underlying interest rate was at 4.56% and moved to 2.81% within the simulated period. The swaption for EUR 100 notional was purchased at EUR 2.20[7] and the value increased to EUR 33.47 at the expiration on December 3rd, 2008. The delta of the ATM swaption was equal to -0.48 at purchase. Due to the decreasing interest rate in the simulation period, the delta grew to -1.00. In the replicating portfolio this pattern is shown by the notional. The notional started at EUR 48.47 and grew to EUR 100, the standard swaption notional in all further simulations. The DDRS notional is in fact the multiplication of the swaption notional with the swaption delta at a particular moment during the option life time. The development of the IV, the forward interest rate, P&L's of the strategies and the difference are shown in the same table. In this illustrative simulation, the swaption happens to expire in the money. Also, the swaption strategy turns out to be better performing compared to the DDRS. In this specific run, it can be seen that a large relative loss is incurred in the DDRS. In the last column of the table the development of the difference between the swaption P&L and the DDRS P&L is shown (PLD). Two jumps in PLD are remarkably high.

The PLD jumped to EUR 2.19 at October 1st, 2008 from EUR -0.02 at September 24th, 2008. The forward swap rate decreased 40 bps to 4.34%. In the same period the delta of the swaption grew to -0.69 from -0.28. As the delta of the swaption grew gradually to the new level, the increase of the swaption value accelerated during that period. As the delta of the DDRS was constant until the new rebalancing moment at October 1st, 2008, the value increase of the DDRS portfolio occurred at the

[7] The swaption is purchased at EUR 2.20 (offer price). The swaption value in the table is EUR 2.13 (mid price) due to the trading costs (EUR 0.07) of the swaption contract.

initial constant rate of 0.28. This caused the swaption P&L to grow faster than the DDRS P&L. This is a typical example of the impact of the hedging error. Another remarkable point was the development of the IV. In the mentioned period the IV increased by 6.77% point (to 22.81% from 16.04%). The swaption return was positively affected by this development, while the DDRS return was not affected by the IV at all. This contributed to the discrepancy between the P&L of the swaption and the DDRS.

Date	Option maturity left	IV	F	Swaption Notional	Swaption Value	Delta	Swaption PL	DDRS Delta Trade	DDRS Notional	DDRS Gross PL	Delta Trade Costs	DDRS Net PL	PLD
3-9-2008	91	15,35	4,56%	100	2,13	-0,48	-0,07	-0,48	-48,47	0,00	0,04	-0,04	-0,03
10-9-2008	84	15,11	4,57%	100	2,00	-0,47	-0,20	0,01	-47,21	-0,09	0,04	-0,13	-0,08
17-9-2008	77	17,24	4,68%	100	1,49	-0,36	-0,71	0,11	-36,20	-0,84	0,05	-0,90	0,18
24-9-2008	70	16,04	4,74%	100	0,92	-0,28	-1,28	0,08	-27,88	-1,21	0,06	-1,26	-0,02
1-10-2008	63	22,81	4,34%	100	4,88	-0,69	2,67	-0,41	-68,57	0,57	0,09	0,48	2,19
8-10-2008	56	43,12	3,91%	100	12,06	-0,80	9,85	-0,11	-79,63	5,57	0,10	5,47	4,38
15-10-2008	49	37,84	4,42%	100	5,19	-0,56	2,98	0,23	-56,42	-1,28	0,12	-1,41	4,39
22-10-2008	42	35,38	4,23%	100	6,80	-0,72	4,60	-0,15	-71,56	0,49	0,14	0,35	4,25
29-10-2008	35	42,35	3,99%	100	10,34	-0,83	8,13	-0,12	-83,18	3,48	0,15	3,33	4,80
5-11-2008	28	45,92	4,12%	100	8,36	-0,77	6,15	0,06	-76,84	1,53	0,15	1,38	4,77
12-11-2008	21	47,64	4,02%	100	9,64	-0,85	7,44	-0,08	-85,21	2,93	0,16	2,77	4,67
19-11-2008	14	43,65	4,08%	100	8,38	-0,90	6,17	-0,05	-89,83	2,10	0,16	1,94	4,24
26-11-2008	7	70,35	3,52%	100	18,40	-1,00	16,20	-0,10	-99,57	11,35	0,17	11,17	5,03
3-12-2008	0	128,58	2,81%	100	33,47	-1,00	31,27	0,00	-100,00	26,35	0,17	26,18	5,09

***table 2*. Development of different variables during the simulation**[8] **-** Weekly development of the simulation variables like rebalancing date, option maturity left, IV and forward swap rate have been colored grey. The swaption notional, value, P&L and delta have been colored red. Blue colored area shows the DDRS delta trades, notional, gross P&L, net P&L and the trading costs. In the last column, the PLD (difference between swaption P&L and the DDRS P&L) is given in green for positive numbers and red colors for negative numbers.

In the week after (October 1st, 2008 to October 8th,2008) the forward swap rate dropped by another 43 bps to 3.91%. The delta of the swaption increased to -0.80. Although the swaption value increased by another EUR 2.19, the main reason was not the growth of the delta this time. As can be seen from the table, the IV increased by 20.31% point to 43.12% in this period. The combination of these two causes led to the increasing difference between the swaption P&L and the DDRS P&L.

[8] F = forward swap rate, swaption market spread = 1% point IV, swap market spread = 1 bps

The biggest move in favor of the DDRS occurred in the period between November 12th, 2008 and November 19th, 2008. The swap rate increase by six bps in that period suggests a decrease of the swaption deltas, however that was not the case. In that period the delta grew to -0.90 from -0.85. This surprising effect on the delta was caused by the effect of time to maturity. In this period the time to maturity decreased from fifteen business days to ten business days. Apparently, six bps swap rate increase in combination with rapidly decreasing relative time to maturity increased the probability of the deeply ITM swaption to expire in the money. The combined development of the mentioned variables led to worsening swaption performance compared to the DDRS performance. In this period the swaption lost EUR 1.27 in value, while the DDRS portfolio lost only EUR 0.83.

4 Empirical results

In this chapter simulation results are given. Every paragraph contains a set of parameters and simulation results according to the given set of parameters. In addition to this, sensitivity analysis will be given for some of the variables.

4.1 Base case

The parameters of the base case are as stated in *table 3*. Most importantly, the base case assumes 0 trading costs for both swaptions and swaps. This assumption will be relaxed in further investigations.

Variable	Base Case
Moneyness	ATM
Swap maturity	30 years
Option maturity	1 - 60 months
Start date simulations	2nd day of every month between April 2, 2002 and April 8, 2011
Swaption market spread	0% point IV
Swap market spread	0 bps
Rebalancing period for DDRS	1 day

***table 3.* Base case parameters –** Base case simulation parameters are shown. 1-60 months option on 30 years swaps is initiated every 2nd day of the months between April 2nd, 2002 and April 2nd, 2011. No costs are taken into account for the swaption and the swap trades. The DDRS rebalancing is performed daily.

4.1.1 Simulation results

For the base case, the results are shown in *table 4*. The results of the simulations have been arranged in matrix form. On the horizontal axis, different start dates and on the vertical axis different swaption maturities have been put. The (sub)diagonals from left down corner to right upper corner contain simulations that have the same expiration date. The values in the matrix represent the PLDs which is defined as the difference between the swaption strategy P&L and the DDRS P&L in Euros. Positive numbers are in favor of the swaption strategy, negative numbers are in favor of the DDRS. The exact numerical result of each simulation is not the most interesting feature at this stage of the analysis. Rather, it is interesting to see whether it is possible to distinguish patterns, which provide a first indication of the situations in which either the swaptions or the DDRS performs best. Therefore, in the table, simulations in which the swaption strategy performed better have been colored purple, while the yellow colors show simulation results in which DDRS performed better.

	apr-02	mai-02	jun-02	jul-02	aug-02	sep-02	okt-02	nov-02	des-02	jan-03	feb-03	mar-03	apr-03	mai-03	jun-03	jul-03	aug-03	sep-03
1	0,02	-0,38	0,06	0,14	0,42	-0,29	-0,19	-0,01	-0,11	0,02	-0,35	0,23	-0,48	0,13	0,60	0,03	-0,20	-0,05
2	-0,13	-0,12	0,22	0,33	0,32	-0,28	-0,20	-0,10	0,07	0,01	0,06	0,00	-0,32	0,37	0,39	0,01	-0,02	-0,14
3	-0,09	0,06	0,38	0,46	0,17	-0,23	-0,48	-0,03	0,17	-0,16	-0,07	0,01	-0,10	0,63	0,44	-0,04	-0,26	-0,47
4	0,07	0,26	0,57	0,41	-0,09	-0,47	-0,25	0,08	0,20	-0,27	0,44	0,70	-0,11	0,50	0,39	-0,03	-0,41	-0,60
5	0,26	0,46	0,69	0,31	-0,11	-0,21	-0,21	0,12	0,03	-0,10	0,68	0,54	0,08	1,21	0,36	-0,09	-0,70	-0,90
6	0,47	0,61	0,69	0,23	0,00	-0,19	-0,26	-0,01	0,08	0,13	0,56	0,60	0,64	0,70	0,30	-0,20	-0,77	-1,03
7	0,65	0,65	0,69	0,25	0,10	-0,39	-0,44	0,00	0,29	0,36	0,63	0,55	0,22	0,58	0,21	-0,39	-1,07	-0,91
8	0,71	0,66	0,70	0,33	0,12	-0,40	-0,28	0,16	0,61	0,52	0,59	0,52	0,11	0,28	0,09	-0,53	-0,93	-1,29
9	0,74	0,67	0,76	0,41	-0,08	-0,21	-0,03	0,31	0,60	0,65	0,57	0,46	-0,17	0,18	-0,02	-0,73	-1,12	-1,11
10	0,77	0,73	0,86	0,35	-0,02	-0,06	0,33	0,41	0,72	0,47	0,51	0,36	-0,29	-0,12	-0,19	-0,73	-1,18	-1,27
11	0,83	0,81	0,90	0,30	0,17	0,30	0,01	0,49	0,64	0,33	0,43	0,24	-0,51	-0,18	-0,26	-0,82	-1,24	-1,29
12	0,93	0,87	0,90	0,35	0,51	0,42	0,82	0,36	0,37	-0,03	0,32	0,13	-0,64	-0,13	-0,34	-0,89	-1,37	-1,27
13	1,00	0,87	0,91	0,36	0,41	0,95	0,36	-0,15	-0,20	-0,10	0,20	-0,03	-0,58	-0,18	-0,43	-0,97	-1,61	-1,25
14	1,02	0,89	0,95	0,53	0,44	0,47	0,20	-0,16	-0,08	-0,43	0,05	-0,12	-0,65	-0,26	-0,52	-1,11	-1,52	-1,21
15	1,05	0,92	0,99	0,55	0,39	0,34	-0,22	-0,19	-0,31	-0,13	-0,03	-0,20	-0,73	-0,44	[illegible]	[illegible]	-1,50	-1,16
16	1,09	0,95	1,03	0,40	0,10	0,00	-0,23	-0,38	-0,10	-0,42	-0,11	-0,29	-0,90	[illegible]	[illegible]	[illegible]	-1,52	-1,10
17	1,13	0,98	0,99	0,13	-0,17	-0,08	-0,62	-0,29	-0,61	-0,46	-0,19	-0,38	-1,09	[illegible]	[illegible]	[illegible]	-1,46	-1,01
18	1,16	0,94	0,88	0,04	-0,36	-0,36	-0,25	-0,50	-0,30	-0,53	-0,27	-0,47	-1,05	[illegible]	[illegible]	[illegible]	-1,33	-0,88
19	1,15	0,84	0,73	-0,06	-0,71	-0,24	-0,59	-0,87	-0,55	-0,80	-0,37	-0,58	-1,01	[illegible]	[illegible]	[illegible]	[illegible]	-0,72
20	1,07	0,71	0,65	-0,20	-0,44	-0,37	-0,60	-0,74	-0,53	-0,83	-0,46	-0,84	-1,03	[illegible]	[illegible]	[illegible]	[illegible]	-0,56
21	0,95	0,60	0,57	-0,25	-0,95	-0,44	-0,71	-0,79	-0,52	-0,79	-0,70	-0,73	[illegible]	[illegible]	[illegible]	-0,59	[illegible]	-0,40
22	0,86	0,53	0,50	-0,32	-0,68	-0,51	-1,11	-0,76	-0,50	-0,75	-0,59	-0,62	-0,87	-0,23	-0,46	-0,56	-0,70	-0,25
23	0,80	0,46	0,46	-0,64	-0,83	-0,73	-1,00	-0,73	-0,45	-0,75	-0,48	-0,56	-0,74	-0,09	-0,36	-0,44	-0,58	-0,11
24	0,74	0,41	0,39	-0,76	-0,93	-0,85	-0,96	-0,67	-0,39	-0,67	-0,41	-0,46	-0,56	0,08	-0,30	-0,30	-0,43	0,06
25	0,71	0,35	0,25	-0,75	-0,93	-0,79	-0,92	-0,60	-0,33	-0,57	-0,32	-0,32	-0,42	0,22	-0,22	-0,18	-0,27	0,22
26	0,67	0,22	0,16	-0,74	-0,89	-0,75	-0,92	-0,54	-0,23	-0,43	-0,19	-0,22	-0,28	0,35	-0,10	-0,02	-0,13	0,36
27	0,58	0,12	0,12	-0,72	-0,84	-0,76	-0,86	-0,45	-0,10	-0,27	-0,09	-0,16	-0,15	0,46	0,04	0,12	0,01	0,50
28	0,49	0,07	0,10	-0,67	-0,80	-0,68	-0,75	-0,31	0,06	-0,11	-0,03	-0,09	-0,03	0,61	0,15	0,24	0,15	0,63
29	0,43	0,04	0,11	-0,61	-0,73	-0,55	-0,60	-0,16	0,23	0,04	0,05	0,03	0,12	0,76	0,25	0,37	0,27	0,76
30	0,41	0,04	0,14	-0,54	-0,63	-0,41	-0,44	0,00	0,39	0,14	0,18	0,17	0,26	0,89	0,35	0,49	0,39	0,88
31	0,41	0,07	0,20	-0,47	-0,49	-0,24	-0,28	0,17	0,53	0,27	0,32	0,28	0,40	1,02	0,44	0,60	0,50	0,99
32	0,44	0,12	0,25	-0,37	-0,33	-0,07	-0,14	0,32	0,67	0,43	0,42	0,37	0,52	1,13	0,51	0,70	0,61	1,10
33	0,48	0,17	0,33	-0,23	-0,16	0,08	-0,01	0,48	0,83	0,55	0,53	0,48	0,64	1,24	0,60	0,81	0,73	1,21
34	0,54	0,23	0,42	-0,08	0,01	0,20	0,12	0,63	0,97	0,68	0,62	0,56	0,75	1,35	0,68	0,91	0,81	1,28
35	0,60	0,31	0,53	0,06	0,13	0,33	0,26	0,78	1,10	0,80	0,69	0,62	0,84	1,44	0,74	0,98	0,88	1,31
36	0,69	0,42	0,67	0,22	0,26	0,49	0,41	0,93	1,24	0,91	0,77	0,70	0,95	1,54	0,82	1,05	0,86	1,30
37	0,79	0,55	0,81	0,35	0,41	0,64	0,54	1,07	1,37	1,01	0,84	0,78	1,04	1,61	0,82	1,00	0,81	1,27
38	0,93	0,70	0,95	0,50	0,56	0,77	0,67	1,21	1,48	1,12	0,91	0,84	1,12	1,67	0,68	0,95	0,77	1,26
39	1,07	0,81	1,09	0,65	0,70	0,90	0,80	1,33	1,59	1,21	0,96	0,91	1,18	1,66	0,59	0,91	0,77	1,27
40	1,20	0,95	1,24	0,79	0,83	1,02	0,91	1,45	1,69	1,31	1,05	0,91	1,17	1,61	0,54	0,92	0,81	1,31
41	1,34	1,10	1,39	0,92	0,95	1,13	1,03	1,57	1,80	1,38	0,99	0,77	1,12	1,57	0,56	0,97	0,85	1,35
42	1,49	1,24	1,53	1,05	1,06	1,24	1,12	1,69	1,89	1,44	0,85	0,69	1,08	1,55	0,59	1,01	0,91	1,39
43	1,64	1,37	1,66	1,17	1,18	1,34	1,23	1,80	1,96	1,42	0,77	0,65	1,07	1,57	0,63	1,08	0,95	1,43
44	1,77	1,50	1,79	1,29	1,27	1,44	1,32	1,87	1,97	1,37	0,73	0,66	1,10	1,60	0,66	1,13	0,97	1,44
45	1,91	1,63	1,92	1,40	1,37	1,52	1,38	1,92	1,95	1,32	0,76	0,70	1,14	1,65	0,68	1,15	0,97	1,44
46	2,05	1,76	2,04	1,51	1,47	1,58	1,38	1,91	1,91	1,31	0,80	0,74	1,18	1,69	0,65	1,14	0,95	1,40
47	2,17	1,87	2,15	1,61	1,52	1,57	1,34	1,90	1,89	1,33	0,83	0,78	1,22	1,71	0,60	1,12	0,90	1,38
48	2,30	1,98	2,28	1,69	1,54	1,52	1,31	1,89	1,90	1,36	0,87	0,80	1,25	1,71	0,53	1,08	0,94	1,39
49	2,42	2,10	2,38	1,74	1,52	1,49	1,30	1,91	1,93	1,40	0,87	0,78	1,26	1,69	0,62	1,13	0,87	1,35
50	2,55	2,21	2,46	1,76	1,48	1,48	1,32	1,94	1,96	1,44	0,83	0,73	1,24	1,62	0,53	1,03	0,80	1,28
51	2,66	2,28	2,51	1,74	1,46	1,51	1,36	1,99	2,01	1,46	0,77	0,66	1,18	1,62	0,23	0,97	0,73	1,23
52	2,75	2,33	2,53	1,73	1,48	1,56	1,41	2,04	2,04	1,47	0,68	0,71	1,20	1,61	0,19	0,91	0,67	1,14
53	2,81	2,35	2,54	1,74	1,51	1,61	1,47	2,08	2,06	1,45	0,79	0,67	1,17	1,55	0,19	0,83	0,52	1,08
54	2,84	2,36	2,55	1,76	1,54	1,66	1,50	2,11	2,04	1,38	0,61	0,36	1,11	1,46	-0,07	0,68	0,55	1,04
55	2,86	2,37	2,57	1,79	1,58	1,68	1,51	2,12	2,00	1,38	0,29	0,29	1,02	1,39	-0,10	0,74	0,47	1,02
56	2,88	2,39	2,60	1,82	1,61	1,68	1,49	2,10	1,98	1,34	0,27	0,33	0,96	1,26	-0,04	0,66	0,59	1,07
57	2,91	2,41	2,64	1,86	1,63	1,67	1,45	2,09	1,97	1,27	0,30	0,07	0,83	1,23	-0,12	0,82	0,63	1,06
58	2,94	2,45	2,69	1,89	1,62	1,62	1,45	2,09	1,93	1,19	-0,02	0,20	0,83	1,17	0,10	0,86	0,66	1,19
59	2,97	2,48	2,72	1,89	1,58	1,62	1,44	2,07	1,86	1,13	0,33	0,17	0,77	1,21	0,09	0,91	1,00	1,29
60	3,02	2,52	2,75	1,89	1,55	1,59	1,39	2,02	1,80	1,00	0,14	0,08	0,84	1,26	0,24	1,33	1,06	1,31

	okt-03	nov-03	des-03	jan-04	feb-04	mar-04	apr-04	mai-04	jun-04	jul-04	aug-04	sep-04	okt-04	nov-04	des-04	jan-05	feb-05	mar-05
1	-0,05	-0,39	-0,11	-0,16	-0,35	0,05	-0,30	0,03	-0,12	-0,08	-0,05	-0,03	-0,03	0,13	0,16	-0,09	0,27	0,00
2	-0,25	-0,59	-0,20	-0,40	-0,27	-0,22	-0,26	-0,31	-0,14	-0,15	-0,06	-0,03	-0,02	0,22	0,18	0,19	0,16	-0,07
3	-0,75	-0,53	-0,39	-0,35	-0,74	-0,18	-0,36	-0,28	-0,17	-0,16	-0,06	-0,07	0,04	0,29	0,25	0,13	-0,07	-0,06
4	-0,54	-0,73	-0,38	-0,70	-0,54	-0,31	-0,73	-0,40	-0,19	-0,17	-0,10	-0,04	0,12	0,37	0,38	0,04	0,10	0,04
5	-1,08	-0,65	-0,57	-0,77	-0,83	-0,66	-0,65	-0,44	-0,20	-0,20	-0,11	0,03	0,21	0,46	0,41	0,05	0,46	0,23
6	-0,82	-0,92	-0,91	-0,89	-0,83	-0,62	-0,66	-0,46	-0,20	-0,22	-0,08	0,11	0,29	0,52	0,41	0,12	0,50	0,33
7	-1,04	-1,03	-0,90	-1,01	-0,88	-0,63	-0,65	-0,46	-0,18	-0,16	0,03	0,23	0,40	0,59	0,46	0,32	0,34	0,37
8	-0,92	-1,05	-0,98	-1,03	-0,88	-0,62	-0,67	-0,43	-0,13	-0,06	0,16	0,35	0,47	0,64	0,58	0,34	0,36	0,43
9	-1,03	-1,15	-0,99	-1,03	-0,86	-0,64	-0,65	-0,36	-0,06	0,06	0,29	0,45	0,53	0,75	0,69	0,36	0,35	0,46
10	-1,23	-1,14	-0,99	-1,01	-0,85	-0,62	-0,58	-0,25	0,04	0,19	0,41	0,52	0,63	0,87	0,73	0,40	0,36	0,49
11	-1,19	-1,12	-0,96	-0,98	-0,82	-0,56	-0,49	-0,14	0,14	0,30	0,50	0,60	0,73	0,95	0,78	0,38	0,35	0,53
12	-1,16	-1,07	-0,93	-0,95	-0,75	-0,46	-0,37	-0,01	0,26	0,41	0,60	0,71	0,81	1,02	0,82	0,40	0,37	0,59
13	-1,12	-1,03	-0,89	-0,88	-0,64	-0,33	-0,24	0,12	0,38	0,51	0,72	0,83	0,90	1,11	0,86	0,44	0,27	0,58
14	-1,11	-0,98	-0,83	-0,78	-0,50	-0,18	-0,11	0,24	0,49	0,64	0,85	0,93	1,00	1,19	0,91	0,46	0,47	0,65
15	-1,06	-0,90	-0,73	-0,65	-0,37	-0,06	0,01	0,34	0,61	0,78	0,96	1,03	1,07	1,25	0,96	0,33	0,25	0,54
16	-0,97	-0,78	-0,60	-0,51	-0,23	0,07	0,11	0,48	0,75	0,89	1,07	1,12	1,13	1,32	1,00	0,52	0,13	0,56
17	-0,84	-0,64	-0,47	-0,37	-0,10	0,18	0,25	0,61	0,87	1,00	1,17	1,19	1,20	1,38	0,93	0,39	0,05	0,31
18	-0,68	-0,49	-0,33	-0,24	0,02	0,31	0,38	0,74	0,99	1,10	1,25	1,27	1,26	1,41	1,29	0,38	0,01	0,33
19	-0,53	-0,32	-0,19	-0,12	0,17	0,45	0,51	0,86	1,10	1,19	1,34	1,34	1,30	1,53	0,67	0,19	-0,07	0,43
20	-0,38	-0,19	-0,07	0,02	0,30	0,57	0,62	0,96	1,20	1,27	1,41	1,39	1,36	1,40	0,69	0,18	0,18	0,42
21	-0,25	-0,05	0,07	0,17	0,43	0,69	0,73	1,06	1,31	1,36	1,48	1,44	1,32	1,27	0,70	0,32	0,15	0,43
22	-0,12	0,10	0,21	0,30	0,56	0,80	0,82	1,16	1,40	1,44	1,53	1,46	1,18	1,18	0,72	0,26	0,08	0,45
23	0,02	0,25	0,34	0,42	0,66	0,89	0,91	1,24	1,48	1,50	1,56	1,35	1,09	1,15	0,78	0,29	-0,27	0,12
24	0,18	0,39	0,47	0,54	0,77	0,99	1,00	1,33	1,57	1,53	1,50	1,26	1,05	1,18	0,80	0,27	-0,30	0,09
25	0,31	0,54	0,59	0,65	0,88	1,08	1,09	1,40	1,63	1,52	1,42	1,20	1,06	1,21	0,83	-0,18	-0,39	-0,33
26	0,44	0,66	0,71	0,76	0,98	1,17	1,16	1,45	1,65	1,46	1,37	1,20	1,08	1,24	0,82	-0,11	-0,52	-0,18
27	0,57	0,77	0,81	0,86	1,08	1,24	1,21	1,44	1,63	1,41	1,35	1,22	1,11	1,27	0,69	-0,40	-0,60	-0,25
28	0,68	0,89	0,92	0,96	1,17	1,29	1,19	1,39	1,59	1,39	1,37	1,25	1,14	1,25	0,57	-0,39	-0,68	-0,37
29	0,80	1,00	1,03	1,05	1,23	1,27	1,14	1,35	1,58	1,40	1,39	1,28	1,13	1,18	0,61	-0,43	-0,74	-0,44
30	0,89	1,11	1,13	1,11	1,24	1,22	1,09	1,33	1,58	1,42	1,42	1,29	1,08	1,11	0,15	-0,53	-0,79	-0,47
31	1,00	1,21	1,19	1,12	1,21	1,17	1,08	1,35	1,60	1,46	1,45	1,26	1,01	0,92	0,22	-0,59	-0,84	-0,50
32	1,09	1,28	1,22	1,10	1,18	1,16	1,10	1,37	1,63	1,49	1,44	1,21	0,90	1,05	0,16	-0,63	-0,89	-0,50
33	1,15	1,30	1,20	1,06	1,17	1,18	1,14	1,42	1,67	1,50	1,40	1,15	1,00	0,83	0,05	-0,65	-0,93	-0,57
34	1,16	1,29	1,17	1,05	1,19	1,21	1,18	1,45	1,70	1,48	1,35	1,19	0,87	0,61	0,12	-0,64	-0,96	-0,60
35	1,13	1,27	1,16	1,06	1,22	1,24	1,22	1,46	1,71	1,45	1,29	1,17	0,53	0,47	-0,07	-0,68	-0,99	-0,59
36	1,10	1,26	1,17	1,09	1,27	1,28	1,24	1,46	1,70	1,37	1,33	0,92	0,57	0,63	-0,25	-0,71	-1,02	-0,49
37	1,09	1,27	1,19	1,13	1,32	1,30	1,23	1,44	1,66	1,39	1,21	0,88	0,60	0,27	-0,12	-0,69	-1,04	-0,30
38	1,12	1,30	1,23	1,17	1,35	1,29	1,21	1,37	1,63	1,36	1,13	0,84	0,35	0,81	0,02	-0,60	-1,04	-0,26
39	1,16	1,34	1,27	1,20	1,36	1,26	1,14	1,38	1,64	1,30	1,06	0,70	0,58	0,65	0,08	-0,44	-1,00	-0,21
40	1,21	1,38	1,30	1,21	1,36	1,18	1,17	1,36	1,60	1,22	0,97	0,53	0,55	0,54	0,35	-0,39	-0,98	0,75
41	1,26	1,41	1,31	1,21	1,31	1,20	1,13	1,30	1,54	1,17	0,81	0,73	0,42	0,76	0,29	-0,35	-0,73	0,54
42	1,29	1,42	1,30	1,16	1,31	1,16	1,07	1,22	1,49	1,04	0,88	0,58	0,58	0,83	0,46	0,53	-0,56	0,21
43	1,31	1,42	1,27	1,15	1,32	1,10	1,00	1,17	1,41	1,03	0,78	0,75	0,59	1,06	1,22	0,40	-0,52	2,42
44	1,30	1,38	1,24	1,15	1,27	1,02	0,95	1,06	1,34	0,97	0,87	0,72	0,79	1,49	0,78	0,23	0,68	2,83
45	1,26	1,36	1,25	1,11	1,21	0,95	0,81	1,02	1,31	0,99	0,87	0,78	1,20	1,08	0,92	2,22	1,98	3,57
46	1,26	1,36	1,21	1,05	1,16	0,81	0,80	0,96	1,27	1,02	0,88	1,25	0,90	1,08	2,99	2,78	3,38	4,75
47	1,26	1,32	1,15	0,99	1,06	0,77	0,73	0,97	1,29	0,99	1,21	1,08	0,86	2,03	2,65	3,58	4,28	3,61
48	1,22	1,25	1,09	0,90	1,01	0,71	0,77	1,01	1,27	1,19	1,17	1,03	1,67	2,26	3,25	4,76	2,99	4,00
49	1,15	1,20	1,01	0,84	0,97	0,73	0,81	0,99	1,32	1,25	1,12	1,38	1,85	2,85	4,34	3,53	3,58	3,98
50	1,10	1,10	0,93	0,79	0,97	0,76	0,80	1,16	1,39	1,21	1,29	1,71	2,52	3,92	3,57	4,01	2,96	2,92
51	1,01	1,04	0,89	0,78	1,02	0,75	1,02	1,23	1,39	1,29	1,56	2,27	3,58	3,39	3,80	3,80	2,02	2,16
52	0,96	1,00	0,86	0,82	1,02	0,94	1,10	1,22	1,43	1,45	2,08	3,28	2,99	3,54	3,92	2,83	0,89	1,22
53	0,92	0,98	0,89	0,81	1,17	1,02	1,08	1,29	1,41	1,90	3,03	2,91	3,18	3,72	3,10	1,97	0,01	0,68
54	0,93	1,01	0,87	0,91	1,26	0,99	1,17	1,40	1,70	2,72	2,70	3,00	3,35	3,09	2,42	1,07	0,04	0,66
55	0,98	0,99	0,94	1,00	1,26	1,06	1,34	1,84	2,40	2,49	2,77	3,26	2,72	2,47	1,62	0,59	0,03	0,53
56	0,98	1,08	1,03	1,01	1,33	1,20	1,78	2,64	2,17	2,51	3,08	2,74	2,14	1,82	1,11	0,61	-0,10	0,49
57	1,14	1,18	1,04	1,07	1,41	1,63	2,64	2,38	2,16	2,88	2,57	2,18	1,54	1,30	0,83	0,47	-0,30	0,40
58	1,25	1,19	1,08	1,10	1,84	2,45	2,37	2,42	2,52	2,43	2,04	1,60	1,00	0,96	0,72	0,43	-0,04	0,52
59	1,27	1,23	1,09	1,40	2,52	2,26	2,37	2,76	2,15	1,96	1,55	1,12	0,68	0,84	0,65	0,37	-0,16	0,31
60	1,33	1,25	1,34	2,12	2,31	2,16	2,76	2,32	1,71	1,47	1,02	0,78	0,55	0,75	0,56	0,49	-0,55	0,15

table 4. **PLD matrix for base case simulations -** The simulation results are arranged in the table. In the horizontal axis, different initiation dates are put. Vertical axis is used for maturities. The matrix shows the difference between the swaptions P&L and the DDRS P&L, called the P&L Difference or PLD.

B

	apr-05	mei-05	jun-05	jul-05	aug-05	sep-05	okt-05	nov-05	dec-05	jan-06	feb-06	mrt-06	apr-06	mei-06	jun-06	jul-06	aug-06	sep-06	okt-06	nov-06	dec-06	jan-07	feb-07	mrt-07	apr-07	mei-07	jun-07	jul-07	aug-07	sep-07	okt-07	nov-07	dec-07	jan-08	feb-08	mrt-08
1	-0,06	0,12	0,88	-0,36	-0,10	0,23	0,09	0,24	-0,10	-0,01	-0,06	0,08	0,12	0,16	-0,11	-0,08	0,06	0,18	0,17	-0,24	-0,19	-0,09	-0,07	-0,20	-0,01	-0,18	0,25	-0,01	-0,67	-0,18	-0,06	-0,51	0,00	0,13	0,11	-0,08
2	0,02	0,52	0,19	-0,64	-0,02	0,03	-0,03	0,05	0,13	-0,14	-0,07	0,05	0,06	0,06	-0,68	-0,06	0,12	0,05	-0,18	-0,38	-0,26	-0,34	-0,36	-0,31	0,05	-0,19	-0,07	-0,30	-0,54	-0,13	-0,46	-0,32	0,19	-0,02	-0,18	-0,19
3	0,18	0,58	-0,05	-0,58	-0,28	-0,02	-0,31	0,02	-0,15	-0,22	-0,11	-0,01	0,12	-0,53	-0,25	0,00	0,14	0,05	-0,47	-0,40	-0,32	-0,41	-0,36	-0,35	-0,01	-0,15	-0,24	-0,19	-0,25	-0,46	-0,55	0,14	0,10	0,02	-0,20	0,00
4	0,34	0,43	0,08	-0,37	0,24	-0,09	-0,27	-0,16	-0,26	-0,32	-0,18	-0,06	0,07	-0,08	-0,15	0,09	0,14	-0,43	-0,53	-0,45	-0,40	-0,52	-0,33	-0,39	-0,05	-0,15	0,02	-0,13	-0,59	0,07	-0,10	0,02	0,16	-0,10	0,02	0,54
5	0,26	0,46	0,10	-0,44	-0,02	-0,33	-0,41	-0,17	-0,36	-0,42	-0,24	-0,10	-0,06	0,04	-0,12	0,12	0,16	-0,38	-0,61	-0,53	-0,51	-0,61	-0,41	-0,44	-0,06	-0,09	0,10	-0,32	0,06	0,05	-0,14	-0,04	0,15	0,19	0,61	0,19
6	0,26	0,49	0,14	-0,72	0,10	-0,32	-0,54	-0,26	-0,46	-0,51	-0,29	-0,13	0,21	0,11	-0,11	0,16	-0,22	-0,63	-0,72	-0,61	-0,60	-0,69	-0,48	-0,50	-0,05	-0,11	-0,13	-0,75	-0,20	0,00	0,01	0,10	0,35	0,74	0,24	0,02
7	0,29	0,50	-0,02	-0,48	-0,13	-0,38	-0,64	-0,37	-0,53	-0,59	-0,32	-0,21	0,08	0,12	-0,07	0,12	-0,24	-0,67	-0,81	-0,68	-0,69	-0,76	-0,52	-0,53	-0,02	-0,26	0,26	-0,13	-0,25	0,12	0,07	0,35	0,82	0,20	0,13	2,75
8	0,25	0,52	0,20	-0,64	-0,23	-0,47	-0,74	-0,45	-0,60	-0,67	-0,37	0,00	0,16	0,15	-0,34	-0,05	-0,53	-0,77	-0,90	-0,76	-0,78	-0,82	-0,54	-0,54	-0,06	-0,17	0,41	-0,16	-0,09	0,22	0,08	0,97	0,40	0,21	2,57	2,55
9	0,27	0,53	-0,09	-0,72	-0,33	-0,56	-0,82	-0,52	-0,67	-0,74	-0,18	-0,34	-0,10	-0,13	-0,42	-0,16	-0,45	-0,84	-0,99	-0,84	-0,87	-0,88	-0,53	-0,55	-0,07	0,01	0,36	0,00	-0,01	0,43	0,46	0,28	0,36	2,28	2,34	3,50
10	0,30	0,43	-0,21	-0,81	-0,44	-0,65	-0,91	-0,57	-0,72	-0,80	-0,40	-0,34	-0,19	-0,24	-0,69	-0,12	-0,54	-0,90	-1,07	-0,90	-0,96	-0,93	-0,58	-0,57	-0,02	0,09	0,38	-0,01	0,22	0,36	0,20	0,45	2,32	2,08	3,40	4,93
11	0,27	0,67	-0,29	-0,88	-0,53	-0,72	-0,98	-0,65	-0,72	-0,82	-0,46	-0,37	-0,50	-0,50	-0,56	-0,46	-0,65	-0,95	-1,14	-0,96	-1,03	-0,96	-0,62	-0,59	0,10	0,48	0,56	0,21	0,50	0,44	0,13	2,85	2,17	2,79	4,19	4,34
12	0,47	0,45	-0,37	-0,95	-0,60	-0,81	-1,04	-0,25	-0,72	-0,88	-0,50	-0,42	-0,49	-0,41	-0,69	-0,53	-0,71	-1,01	-1,21	-1,02	-1,11	-1,01	-0,59	-0,54	0,34	0,34	0,75	0,35	0,21	0,39	1,69	2,46	2,93	3,91	3,44	4,80
13	0,28	0,35	-0,45	-1,01	-0,65	-0,87	-1,09	-0,86	-0,85	-0,95	-0,54	-0,48	-0,62	-0,53	-0,81	-0,55	-0,75	-1,06	-1,26	-1,07	-1,16	-1,04	-0,46	-0,46	0,38	0,59	1,22	0,04	0,13	2,05	1,73	3,15	3,98	3,42	3,71	4,90
14	0,14	0,27	-0,51	-1,08	-0,72	-0,94	-1,11	-0,80	-0,92	-1,02	[illegible]	[illegible]	[illegible]	-0,67	-0,86	-0,61	-0,75	-1,09	-1,31	-1,12	-1,22	-1,02	-0,25	-0,32	0,47	1,31	0,89	0,15	1,68	2,10	2,55	4,25	3,48	3,62	3,77	4,03
15	0,10	0,24	-0,55	-1,12	-0,58	-0,98	-1,18	-0,85	-0,98	-1,08	[illegible]	-0,61	[illegible]	-0,71	-0,88	-0,54	-0,73	-1,12	-1,35	-1,17	-1,27	-0,98	-0,22	-0,28	0,96	1,08	0,82	0,97	1,71	2,85	3,60	3,67	3,72	3,89	3,06	3,37
16	0,05	0,20	-0,60	-1,13	-0,88	-1,02	-1,26	-0,91	-1,04	-1,15	[illegible]	-0,68	[illegible]	-0,73	-0,86	-0,62	-0,80	-1,15	-1,39	-1,21	-1,30	-0,90	-0,19	-0,11	1,07	0,92	2,72	1,35	2,51	3,94	3,22	3,94	3,98	3,23	2,42	2,47
17	-0,33	0,25	-0,57	-1,11	-0,84	-1,08	-1,33	-0,99	-1,11	-1,21	[illegible]	[illegible]	[illegible]	-0,71	-0,83	-0,82	-0,81	-1,18	-1,42	-1,23	-1,32	-0,88	0,26	0,11	0,97	3,48	2,63	2,16	3,61	3,45	3,46	4,17	3,34	2,67	1,60	1,77
18	0,18	0,42	-0,56	-1,20	-0,87	-1,14	-1,40	-1,07	-1,18	-1,28	[illegible]	-0,82	[illegible]	-0,67	-0,90	-0,68	-0,70	-1,14	-1,42	-1,24	-1,34	-0,76	0,37	0,19	2,21	3,23	3,43	3,21	3,15	3,70	3,77	3,46	2,77	1,96	1,03	1,39
19	0,09	0,36	-0,69	-1,26	-0,92	-1,20	-1,47	-1,16	-1,26	-1,36	[illegible]	-0,88	[illegible]	-0,74	-0,89	-0,32	-0,51	-1,08	-1,41	-1,24	-1,34	-0,58	0,30	0,35	3,61	4,02	4,59	2,91	3,39	3,92	3,15	2,87	2,00	1,36	0,76	1,16
20	0,13	0,03	-0,73	-1,30	-0,98	-1,27	-1,54	-1,25	-1,34	-1,43	[illegible]	[illegible]	[illegible]	-0,73	-0,73	-0,29	-0,28	-1,02	-1,39	-1,24	-1,31	-0,51	1,64	2,76	4,38	5,18	3,94	3,11	3,68	3,32	2,63	2,12	1,47	1,03	0,66	1,01
21	-0,20	-0,01	-0,76	-1,34	-1,05	-1,32	-1,61	-1,34	-1,43	-1,51	-1,06	-0,99	-0,87	-0,64	-0,61	-0,11	-0,40	-1,04	-1,38	-1,20	-1,29	0,48	2,87	3,78	5,57	4,26	4,20	3,43	2,99	2,70	1,92	1,49	1,11	0,89	0,58	0,80
22	-0,22	-0,09	-0,81	-1,39	-1,12	-1,39	-1,69	-1,42	-1,51	-1,59	-1,12	-1,04	-0,89	-0,54	-0,42	-0,32	-0,40	-0,89	-1,30	-1,16	-1,20	1,94	3,84	4,94	4,40	4,61	4,31	2,82	2,39	1,93	1,32	1,17	0,96	0,80	0,50	0,73
23	-0,66	-0,22	-0,86	-1,44	-1,20	-1,45	-1,77	-1,50	-1,59	-1,66	-1,17	-1,09	-0,88	-0,35	-0,54	-0,19	0,26	-0,76	-1,25	-1,15	1,41	3,09	4,82	3,46	4,85	4,65	3,62	2,29	1,69	1,38	0,98	1,06	0,87	0,72	0,54	0,53
24	-0,50	-0,28	-0,91	-1,49	-1,26	-1,52	-1,85	-1,58	-1,66	-1,74	-1,23	-1,13	-0,84	-0,40	-0,47	0,67	0,16	-0,71	-1,21	1,53	2,60	4,15	3,59	4,22	4,77	3,70	2,98	1,63	1,06	1,04	0,86	0,99	0,79	0,76	0,45	0,25
25	-0,63	-0,36	-0,97	-1,56	-1,34	-1,58	-1,89	-1,64	-1,72	-1,81	-1,28	-1,17	-0,77	-0,36	0,32	0,20	-0,08	0,50	1,32	2,63	3,02	2,84	4,13	3,95	3,73	3,01	2,19	1,02	0,72	0,91	0,77	0,89	0,81	0,69	0,28	0,09
26	-0,68	-0,42	-1,05	-1,62	-1,40	-1,65	-1,93	-1,70	-1,79	-1,87	-1,33	-1,20	-0,77	0,44	0,15	0,15	1,58	1,60	2,57	3,38	2,03	3,47	3,85	2,84	2,85	2,04	1,65	0,68	0,59	0,84	0,69	0,94	0,75	0,55	0,16	0,00
27	-0,72	-0,47	-1,12	-1,68	-1,46	-1,70	-1,96	-1,76	-1,84	-1,93	-1,37	-1,22	-0,42	0,31	-0,18	2,67	2,52	3,13	3,43	2,27	2,54	3,02	2,89	1,59	1,86	1,44	1,36	0,56	0,50	0,76	0,73	0,86	0,61	0,39	0,09	-0,06
28	-0,78	-0,52	-1,18	-1,75	-1,52	-1,76	-1,99	-1,81	-1,89	-2,00	-1,41	-1,22	-0,22	0,00	1,82	2,36	3,33	4,08	2,25	2,78	0,76	1,95	1,95	0,94	1,37	1,36	1,25	0,47	0,41	0,81	0,68	0,71	0,46	0,31	0,05	0,16
29	-0,83	-0,57	-1,25	-1,81	-1,58	-1,83	-2,02	-1,86	-1,95	-2,05	-1,43	-1,14	-0,21	1,89	2,51	3,14	4,53	2,83	2,81	1,26	0,69	0,65	0,97	0,76	1,50	1,25	1,19	0,42	0,45	0,75	0,56	0,56	0,37	0,26	0,30	0,47
30	-0,86	-0,60	-1,30	-1,86	-1,63	-1,88	-2,05	-1,90	-1,99	-2,11	-1,39	-1,08	1,09	2,66	3,31	4,27	3,38	3,44	2,07	0,83	0,94	0,13	0,57	0,83	1,35	1,23	1,12	0,46	0,39	0,63	0,41	0,49	0,32	0,44	0,63	0,72
31	-0,89	-0,63	-1,35	-1,92	-1,67	-1,94	-2,07	-1,93	-2,02	-2,15	-1,35	-1,04	2,38	3,47	4,52	3,33	3,87	2,81	1,04	1,01	0,88	0,05	0,72	0,61	1,36	1,13	1,18	0,43	0,26	0,49	0,34	0,45	0,49	0,74	0,90	0,98
32	-0,91	-0,67	-1,41	-1,97	-1,71	-2,00	-2,09	-1,93	-2,00	-2,17	-1,23	1,72	3,49	4,65	3,40	3,70	3,75	1,86	0,79	0,91	0,63	0,06	0,56	0,70	1,31	1,25	1,10	0,34	0,10	0,41	0,28	0,67	0,78	1,00	1,18	1,22
33	-0,94	-0,70	-1,46	-2,02	-1,74	-2,05	-2,10	-1,84	-1,96	-2,18	1,37	2,82	4,63	3,54	3,87	3,65	2,75	1,19	0,60	0,63	0,03	-0,01	0,57	0,70	1,46	1,09	0,95	0,20	0,02	0,36	0,45	1,00	1,07	1,27	1,48	1,60
34	-0,96	-0,71	-1,50	-2,06	-1,75	-2,10	-2,09	-1,78	-2,06	0,02	2,73	3,60	3,34	4,02	3,71	2,79	1,86	0,01	0,24	-0,07	0,03	-0,19	0,57	0,69	1,17	0,91	0,82	0,13	-0,04	0,56	0,75	1,30	1,32	1,53	1,83	1,70
35	-0,95	-0,70	-1,53	-2,09	-1,73	-2,13	-2,06	-1,74	0,83	1,44	3,22	2,45	3,90	3,95	2,79	2,09	0,96	-0,03	-0,55	0,06	0,21	0,05	0,67	0,32	1,04	0,80	0,76	0,08	0,11	0,84	1,00	1,55	1,55	1,86	1,94	1,49
36	-0,90	-0,66	-1,55	-2,12	-1,61	-2,14	-2,02	0,97	1,93	1,80	2,24	2,97	3,59	2,91	1,98	1,21	0,43	-0,02	-0,27	0,22	-0,16	-0,12	0,35	0,31	0,96	0,75	0,71	0,20	0,43	1,12	1,29	1,80	1,91	2,05	1,74	1,16
37	-0,81	-0,62	-1,55	-2,10	-1,54	-2,15	0,46	2,14	2,59	0,95	2,65	2,25	2,50	2,13	1,04	0,65	0,50	-0,09	-0,17	0,06	-0,05	-0,44	0,22	0,25	0,93	0,73	0,94	0,49	0,69	1,40	1,52	2,17	2,11	1,88	1,43	0,83
38	-0,77	-0,40	-1,47	-2,06	-1,49	0,08	1,83	2,98	1,66	1,32	0,91	1,03	1,52	1,14	0,51	0,52	0,38	-0,29	-0,18	-0,12	-0,61	-0,32	0,14	0,24	0,99	1,10	1,26	0,76	0,99	1,64	1,89	2,36	1,94	1,60	1,11	
39	-0,31	-0,19	-1,40	-2,03	1,11	1,54	2,22	1,89	1,99	0,42	0,42	1,18	0,58	0,60	0,53	0,43	0,36	-0,02	-0,55	-0,62	-0,69	-0,44	0,11	0,48	1,52	1,50	1,53	1,02	1,21	2,00	2,11	2,18	1,67	1,27		
40	-0,15	-0,11	-1,35	0,84	2,39	1,90	1,40	2,34	0,82	0,25	0,99	1,07	0,36	0,65	0,40	0,39	0,28	-0,14	-0,80	-0,48	-0,84	-0,47	0,23	1,23	1,95	1,78	1,81	1,26	1,58	2,19	1,96	1,89	1,36			
41	-0,15	1,40	1,54	2,03	3,28	1,07	1,67	0,91	0,00	0,52	0,91	0,77	0,45	0,51	0,39	0,30	0,42	-0,47	-0,61	-0,68	-0,48	0,01	0,82	1,65	2,22	2,09	2,08	1,63	1,79	2,02	1,71	1,57				
42	1,17	2,53	2,61	2,44	2,16	1,40	0,60	0,39	0,47	0,54	0,64	-0,14	0,27	0,48	0,30	0,39	0,16	-0,42	-0,81	-0,56	0,81	0,76	1,22	1,85	2,54	2,36	2,48	1,86	1,63	1,74	1,41					
43	2,42	3,61	3,40	1,61	2,64	0,54	0,25	0,36	0,42	0,46	-0,02	0,18	0,26	0,40	0,43	0,24	-0,01	-0,52	-0,80	0,58	1,26	1,11	1,48	2,20	2,85	2,75	2,63	1,73	1,37	1,45						
44	3,54	4,72	2,41	1,97	1,84	0,33	0,57	0,21	0,20	0,23	0,03	0,28	0,25	0,53	0,20	0,07	-0,12	-0,54	0,08	1,22	1,35	1,26	1,77	2,52	3,23	2,89	2,45	1,50	1,06							
45	4,62	3,45	2,81	0,50	0,78	0,57	0,56	-0,15	-0,40	0,11	0,12	0,10	0,28	0,28	0,02	-0,07	-0,17	-0,06	0,85	1,38	1,40	1,60	2,11	2,91	3,29	2,66	2,16	1,21								
46	3,36	4,04	1,15	-0,12	0,47	0,58	0,43	-0,89	-0,33	-0,02	-0,23	-0,15	-0,13	0,09	-0,10	-0,13	-0,14	0,62	1,08	1,44	1,80	1,97	2,51	2,84	3,01	2,31	1,87									
47	3,86	3,64	0,74	0,43	0,30	0,50	0,11	-0,87	-0,33	-0,07	-0,22	-0,60	-0,18	-0,01	-0,15	-0,16	0,29	0,96	1,14	1,81	2,17	2,30	2,50	2,52	2,61	1,99										
48	3,45	2,50	0,95	0,40	-0,09	0,27	0,03	-0,65	-0,67	-0,21	-0,85	-0,40	-0,28	-0,07	-0,15	0,19	0,70	1,15	1,53	2,18	2,48	2,16	2,21	1,95	2,22											
49	2,45	1,17	0,84	0,19	-0,89	0,14	-0,10	-0,79	-0,59	-0,34	-0,79	-0,68	-0,32	-0,07	0,27	0,53	0,96	1,47	1,88	2,50	1,96	1,80	1,75	1,59												
50	1,47	0,86	0,56	-0,38	-0,67	0,00	-0,18	-1,15	-1,05	-0,11	-1,03	-0,63	-0,11	0,37	0,67	0,81	1,28	1,85	2,24	2,09	1,42	1,15	1,39													
51	0,55	0,55	-0,31	-0,28	-0,61	-0,04	-0,32	-1,43	-0,96	-0,60	-0,78	0,34	0,57	0,78	0,93	1,11	1,56	2,24	1,95	1,65	0,70	0,77														
52	0,26	0,56	0,05	-0,31	-0,64	-0,18	-0,51	-1,28	-1,56	0,00	0,41	1,08	0,94	1,04	1,25	1,38	1,95	2,11	1,55	0,87	-0,17															
53	0,37	0,34	0,12	-0,59	-1,21	-0,31	-0,39	-1,50	-1,15	1,13	0,96	1,27	1,14	1,35	1,54	1,77	2,08	1,76	0,81	0,26																
54	0,20	0,39	-0,06	-0,57	-1,26	-0,09	-1,02	-1,47	0,04	1,01	1,04	1,27	1,45	1,62	1,91	1,94	1,85	1,19	0,35																	
55	0,17	0,41	-0,30	-0,97	-1,07	-0,60	-0,51	-0,52	0,56	0,70	1,07	1,67	1,77	2,00	2,05	1,75	1,48	0,84																		
56	0,17	0,44	-0,68	-0,96	-1,28	-0,05	0,69	0,16	0,61	0,75	1,42	2,01	2,13	2,13	1,84	1,47	1,14																			
57	0,25	-0,02	-0,53	-1,48	-1,29	1,10	0,85	0,36	0,60	1,22	1,81	2,34	2,14	1,92	1,50	1,16																				
58	-0,13	0,03	-0,73	-0,98	-0,49	1,05	0,69	0,43	1,01	1,60	2,11	2,01	1,82	1,56	1,17																					
59	-0,19	-0,07	-0,66	0,13	0,18	0,81	0,67	0,77	1,36	1,80	1,68	1,62	1,36	1,26																						
60	-0,27	-0,10	0,32	0,66	0,46	0,79	1,13	1,12	1,67	1,05	1,21	0,86	0,98																							

table 4 (continued)

	apr-08	mei-08	jun-08	jul-08	aug-08	sep-08	okt-08	nov-08	dec-08	jan-09	feb-09	mrt-09
1	-0,04	0,17	0,25	-0,56	-0,11	2,17	0,85	0,22	-0,15	-3,22	-1,83	-1,87
2	0,19	0,69	-0,04	-0,62	2,03	2,25	1,57	0,65	-1,09	-5,59	-3,08	-2,85
3	0,77	0,38	-0,14	0,25	1,78	2,95	2,49	-0,76	-1,86	-5,52	-3,74	-3,32
4	0,33	0,18	1,29	0,62	2,61	4,12	1,24	-0,22	-2,11	-5,76	-3,80	-3,70
5	0,26	2,04	1,45	1,42	3,74	3,49	1,81	-0,69	-2,25	-5,77	-3,87	-3,99
6	2,84	1,98	2,22	2,50	3,21	3,74	1,55	-1,53	-2,24	-5,70	-4,03	-4,21
7	2,38	2,77	3,35	2,34	3,48	3,78	0,52	-2,87	-2,36	-5,85	-4,30	-4,47
8	3,11	3,87	3,06	2,51	3,63	3,04	-0,44	-3,45	-2,43	-5,98	-4,51	-4,68
9	4,28	3,58	3,30	2,88	3,02	2,40	-1,42	-3,50	-2,46	-6,07	-4,64	-4,80
10	3,74	3,82	3,57	2,38	2,39	1,47	-1,66	-3,42	-2,46	-6,08	-4,60	-4,85
11	3,90	4,05	2,98	1,85	1,64	0,86	-1,55	-3,31	-2,42	-6,00	-4,60	-4,84
12	4,12	3,41	2,44	1,20	1,04	0,55	-1,70	-3,22	-2,33	-5,86	-4,53	-4,66
13	3,37	2,88	1,76	0,55	0,64	0,39	-1,65	-3,11	-2,50	-6,05	-4,30	-4,72
14	2,76	2,16	1,09	0,12	0,45	0,28	-1,73	-3,48	-2,66	-6,03	-4,69	-4,89
15	2,00	1,53	0,72	-0,05	0,35	0,15	-1,77	-3,69	-2,81	-6,11	-4,03	-3,38
16	1,36	1,18	0,55	-0,18	0,25	0,22	-2,21	-3,54	-2,92	-6,19	-2,95	-4,42
17	1,06	1,04	0,43	-0,26	0,27	0,07	-2,17	-3,64	-2,99	-4,69	-3,37	-4,89
18	0,94	0,94	0,35	-0,25	0,19	-0,10	-2,25	-3,65	-2,57	-5,58	-3,88	-3,99
19	0,87	0,86	0,36	-0,29	0,03	-0,22	-2,27	-3,07	-2,59	-5,92	-3,48	-3,51
20	0,78	0,88	0,31	-0,38	-0,09	-0,27	-1,96	-2,38	-2,66	-5,18	-3,00	-3,37
21	0,82	0,83	0,18	-0,54	-0,18	-0,30	-1,20	-1,97	-1,35	-4,72	-2,60	-2,92
22	0,74	0,71	0,02	-0,62	-0,23	0,01	-0,80	-1,75	-1,46	-4,52	-2,56	-3,60
23	0,60	0,57	-0,06	-0,68	-0,05	0,37	-0,61	-1,40	-1,94	-4,06	-3,53	-3,99
24	0,45	0,48	-0,13	-0,56	0,27	0,67	-0,25	-0,98	-1,31	-4,80	-3,98	-4,20
25	0,38	0,42	-0,01	-0,31	0,56	0,96	0,09	-0,60	-1,17	-5,26	-4,27	-4,41
26	0,34	0,57	0,26	-0,03	0,83	1,24	0,47	-0,92	-1,35	-5,55	-4,33	
27	0,56	0,84	0,51	0,24	1,09	1,60	0,23	-1,34	-1,54	-5,71		
28	0,87	1,11	0,79	0,47	1,48	1,71	-0,18	-2,09	-1,73			
29	1,16	1,39	1,02	0,84	1,61	1,45	-0,95	-2,61				
30	1,44	1,62	1,36	1,04	1,41	1,03	-1,36					
31	1,70	1,98	1,55	0,89	1,10	0,69						
32	2,06	2,17	1,38	0,64	0,78							
33	2,23	2,00	1,08	0,33								
34	2,02	1,70	0,78									
35	1,73	1,41										
36	1,38											
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	apr-09	mei-09	jun-09	jul-09	aug-09	sep-09	okt-09	nov-09	dec-09	jan-10	feb-10	mrt-10
1	-1,68	-0,61	-1,77	-0,94	-0,66	-0,72	-0,46	-0,48	-0,74	-0,71	-0,49	-1,05
2	-1,73	-1,05	-2,45	-1,23	-1,00	-0,75	-1,00	-1,56	-1,68	-0,85	-0,95	-1,10
3	-2,01	-1,58	-2,79	-1,69	-1,36	-1,18	-1,31	-1,62	-1,92	-1,22	-0,91	-0,16
4	-2,53	-2,34	-3,27	-1,81	-1,39	-1,60	-2,24	-1,57	-2,55	-1,48	0,07	0,31
5	-3,07	-2,58	-3,40	-2,00	-2,26	-2,32	-2,09	-1,91	-2,45	-1,03	0,50	0,31
6	-3,30	-2,64	-3,60	-2,51	-2,44	-2,20	-2,49	-2,10	-1,48	-0,60	0,49	0,20
7	-3,52	-2,90	-4,15	-2,91	-2,36	-2,59	-2,54	-1,61	-1,06	-0,41	0,42	0,52
8	-3,63	-3,04	[illegible]	[illegible]	-2,62	-2,67	-1,66	-0,96	-1,08	-0,38	0,68	0,78
9	-3,76	[illegible]	[illegible]	[illegible]	[illegible]	-1,82	-1,07	-0,72	-1,19	-0,15	0,95	0,94
10	-3,96	[illegible]	-4,59	-3,22	-2,20	-1,22	-0,97	-0,66	-0,92	0,14	1,06	-0,02
11	-3,94	[illegible]	-4,66	-2,97	-1,62	-1,08	-1,02	-0,41	-0,68	0,31	0,14	-1,08
12	-4,46	[illegible]	-4,36	-2,28	-1,35	-1,12	-0,73	-0,14	-0,54	-0,31	-1,18	-1,69
13	-4,07	[illegible]	-3,68	-1,90	-1,23	-0,79	-0,44	0,13	-1,49	-0,98	-1,17	-1,93
14	-2,88	[illegible]	[illegible]	-1,73	[illegible]	-0,46	-0,20	-0,39	-2,60	-1,85	-1,99	
15	-2,56	-1,90	[illegible]	[illegible]	[illegible]	-0,20	-0,95	-0,94	-3,07	-3,09		
16	-2,61	-1,96	-2,84	-1,06	-0,26	-0,88	-1,70	-1,83	-3,59			
17	-2,64	-1,54	-2,52	-0,70	-0,69	-1,61	-2,42	-2,84				
18	-2,18	-1,15	-2,18	-1,00	-1,20	-2,33	-3,31					
19	-1,80	-0,90	-2,48	-1,41	-2,05	-3,32						
20	-1,56	-1,72	-2,89	-2,20	-2,77							
21	-2,49	-2,75	-3,70	-2,74								
22	-3,48	-3,09	-4,20									
23	-3,50	-3,61										
24	-4,02											

	apr-10	mei-10	jun-10	jul-10	aug-10	sep-10	okt-10	nov-10	dec-10	jan-11	feb-11	mrt-11
1	-0,04	0,89	-1,84	-0,69	0,53	-1,49	-1,08	-0,35	-0,90	-0,88	-0,33	-0,19
2	0,98	0,55	-2,22	-0,01	0,89	-1,59	-1,06	-0,27	-1,33	-1,37	-1,10	
3	1,25	0,12	-1,53	0,19	0,96	-1,62	-0,93	-0,47	-1,64	-1,56		
4	1,11	0,18	-1,44	0,08	0,75	-1,37	-1,04	-0,75	-1,88			
5	0,94	0,63	-1,71	1,12	0,07	-1,39	-1,25	-1,01				
6	1,21	0,93	-0,67	0,09	-0,28	-1,50	-1,45					
7	1,45	0,94	-1,55	-0,36	-0,55	-1,65						
8	1,53	-0,24	-1,97	-0,63	-0,74							
9	0,43	-0,86	-2,26	-0,87								
10	-0,65	-1,13	-2,49									
11	-1,53	-1,12										
12	-1,38											

table 4 (continued)

When the PLDs are considered for different expiration dates, some dates look like a turning point regarding the relative efficiency of one strategy compared to the other strategy. This can be seen from the color patterns in *table 4*.

1) The simulations with swaption maturities from one month up to 40 months expiring before August 2008, show the relative superior performance of the DDRS. In contradiction, for simulations which expired in September 2008 and within a couple of months after September 2008, the swaption strategy performed relatively better. From August 2008 to November 2008 the swaption strategy gained about EUR 2 relative to the DDRS for the mentioned maturities. The reason was the move of the interest rate in one direction. At any day, the DDRS was less sensitive to large changes of the underlying interest rate, compared to the swaption strategy. This caused the swaption strategy to become relatively more efficient compared to the DDRS around that period. The results show that the swaption strategy performed relatively better for simulations which expired during the crisis.

2) The same pattern is observed for simulations with maturities from 40 up to 60 months which expired around May 2010. The swaption strategy gained about EUR 1 relative to the DDRS. The turning point is again characterized by decreasing interest rates.

In general, in the matrix three areas can be distinguished in which the DDRS has performed better than the swaption strategy. These areas have been labeled A, B and C in the table.

3) Area A is the period starting around July 2002. The simulations with maturities between 20 up to 34 months which started around July 2002, turned out to be in favor of the DDRS. These simulation runs finished in the period between March 2004 and May 2005. Between July 2002 and March 2004, the long maturity interest rates showed a relatively stable development. From March 2004 until May 2005 the interest rates declined gradually. In the period of stable interest rate development, the DDRS was more efficient than the swaption strategy. As soon as the interest rates started decreasing, the swaption strategy became more efficient.
4) Area B is the period starting after January 2005. The simulation results show that the DDRS with maturities from 25 up to 41 months performed better compared to the swaption strategy. The shorter maturities became in favor of the DDRS after June 2005. The simulations of relatively efficient DDRS finished in the first half of 2008. Between January 2005 and the first half of 2008 the interest rates increased about 1% point overall, however the climb was characterized by relatively stable sub periods.

5) Area C is the period starting in October 2008. After that month, DDRS became relatively more efficient for maturities up to 30 months (other maturities are not simulated, due to absence of data to finish the simulations). After the historically low levels in December 2008, the interest rates recovered very rapidly in that period. A combination of relatively high swaptions IV and increasing interest rates led to worsening of the swaption performance relative to the DDRS performance. The contribution of the relatively high swaption premium to the results during this period is obvious. The average swaption P&L in that specific period was EUR -1.01, while the average DDRS P&L was EUR 0.97.

In the periods discussed under number three and four, the interest rate was relatively stable and the IV was low. In the period discussed under number five, the interest rate increased, interest development was more volatile and as a consequence the IV was high. From this we can draw several initial conclusions:

<u>Conclusion 1:</u> Stable periods result in favor of the DDRS.

Because of the stable interest rate, only few trades are needed to execute the DDRS, resulting in low transaction costs.

<u>Conclusion 2:</u> Unstable periods with high IV at inception also favors the DDRS.

The high IV increased the swaption prices such that the swaption became inferior to the DDRS.

<u>Conclusion 3:</u> In circumstances of decreasing interest rates the swaption performed better.

In the simulations in which the swaptions had positive return, the swaption strategy performed better than the DDRS. The simulations in which swaption P&L was negative (not necessarily expired out the money) the DDRS performed better. In the environment of stable or increasing interest rates the swaptions strategy lost its relative efficiency compared to the DDRS. This is summarized in *table 5*. In this table, the number of positive and negative PLDs are given for simulations in which swaptions have positive and negative returns. In the last row, the average swaption P&L is given for positive PLD observations and negative PLD observations.

	Swaption P&L > DDRS P&L	Swaption P&L < DDRS P&L
# swaption P&L > 0	2097	793
# swaption P&L < 0	434	1386
Average swaption P&L	EUR 5.65	EUR -1.61

table 5. **Distribution of positive and negative P&L's for positive and negative P&L's** –The table shows the relative efficiency of the swaption strategy for simulations in which the swaption expires in the money. In case of swaptions expiring out of the money, the DDRS turns out to be performing better.

4.1.2 Base case simulation results in key figures

The distribution of the PLD for 4710 simulations is given in *figure 16*. On the x-axis the PLD is given in Euros, on the y-axis the frequency is given. The PLD distribution is bell shaped. 1820 (39%) simulations resulted in a PLD, in favor of the DDRS (negative outcomes). 2890 (61%) simulations resulted in a PLD in favor of the swaption strategy (positive outcomes). On average the swaption strategy performed better by EUR 0.33 per simulation. Compared to EUR 4.60 average swaption premium, this difference is about 7.17% of the swaption premium.

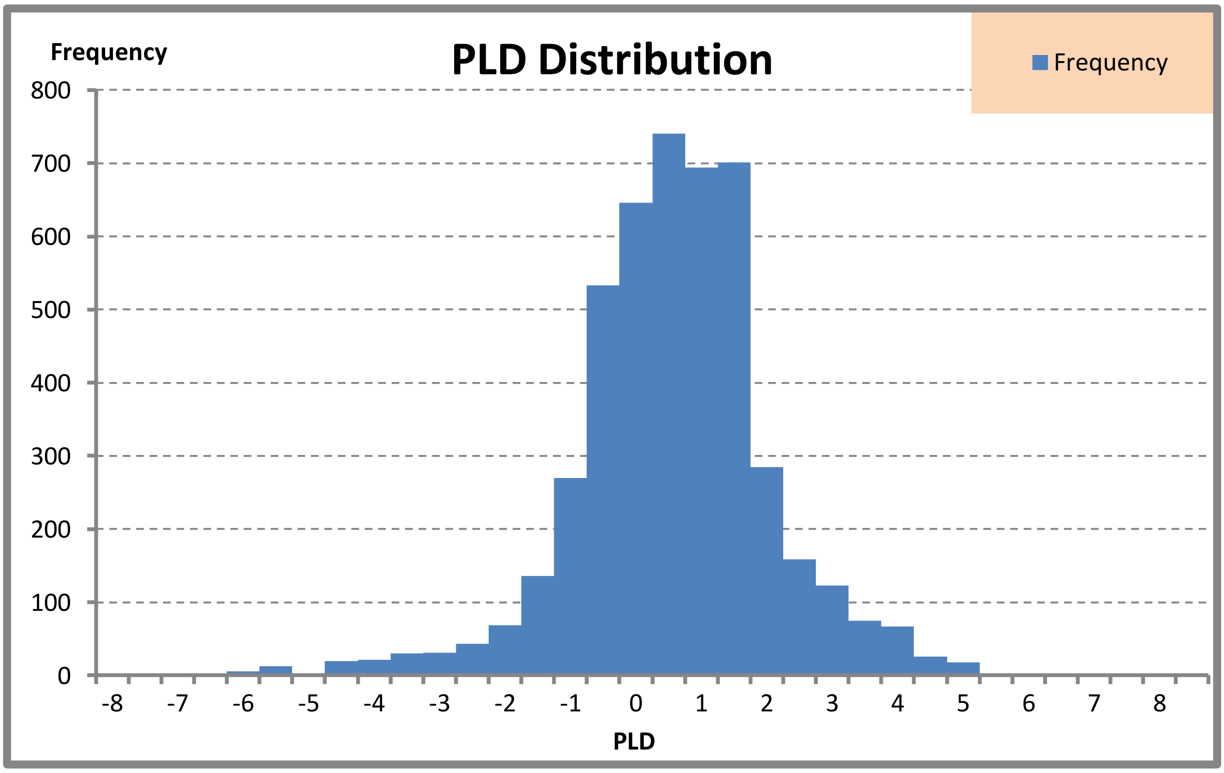

figure 16. **Frequency distribution of PLDs** - This graph shows the distribution of the difference between the swaption P&L and the DDRS P&L.

When the results for different maturities are analyzed separately, the distribution changes. The short maturity swaptions on average turn out to be performing worse than the DDRS. However when the long maturity swaptions are analyzed, the swaptions turn out to be more efficient on average. The percentage of swaptions performing better than the DDRS grew when the swaption maturity increased. 36 out of 108 (33.33%) simulations with one month maturity showed the relative efficiency of the swaption strategy. This ratio went up to 46 out of 49 simulations (93.88%) for 60 months maturity swaptions. The average PLDs for different maturities are shown in *figure 17*. A note has to be made here that the number of analyzed long maturity swaptions is lower compared to the short maturity swaptions. Starting from April 2006, we could not fully simulate 5-year swaptions anymore, given the fact that available data runs up until April 2011. Going forward from April 2006, this is true for increasingly more swaptions maturities. Therefore the analysis is biased towards the longer maturity swaptions which are purchased before April 2006. However, the results still indicate a fourth cautious conclusion:

Conclusion 4: For lower maturity swaptions, delta replication offers better possibilities than for higher maturity swaptions.

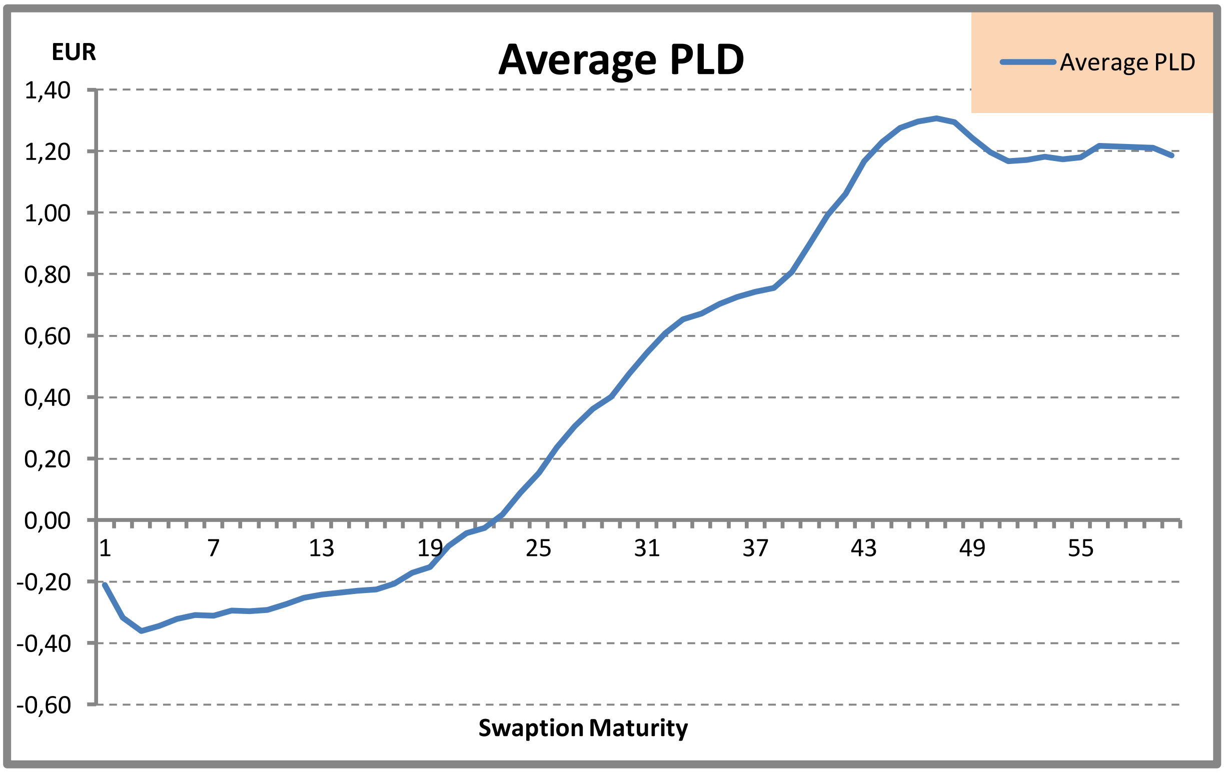

***figure 17.* Average PLDs** - The development of the average PLDs for maturities from one month up to 60 months. Average PDLs increased for higher maturities.

As the swaption IV increased after January 2008, the simulations for longer maturity swaptions purchased at a high IV are not available. While my analysis includes the cheap and more expensive short maturity swaptions, for the longer maturity swaptions this was not possible and in my sample the relatively expensive long maturity swaptions are underrepresented. The relative efficiency of the swaptions in the longer maturity simulations might be partly explained by this bias. In *figure 18* the second highest and the second lowest values for the PLDs are shown. The maximum and the minimum values have been eliminated in order to avoid granting high weights to the outliers. From the figure, it is observed that the distribution of the PLD is much wider for maturities up to 28 months than for longer maturities. This is especially true for the lower bound of the range for maturities higher than 28 months, which means that the best simulations in favor of the DDRS (negative outcomes) performed relatively worse for the higher maturities. This is most likely caused by the absence of long maturity swaptions purchased at a high IV.

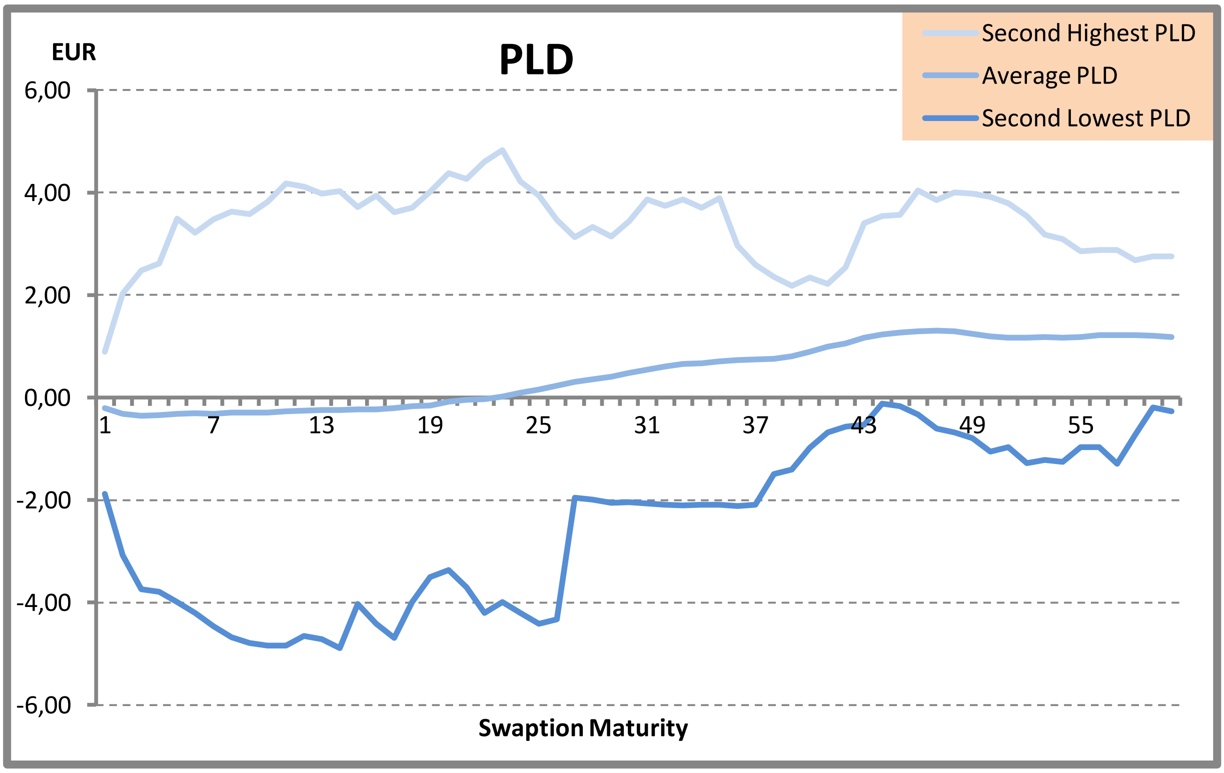

figure 18. **Average PLD, second highest PLD, second lowest PLD -** Range of second highest PLD and second lowest PLD in contrast with the average PLD for maturities from one month up to 60 months. The PLD range is high for all maturities.

Table 6 shows the key figures of the simulations. The overall statistics show that the swaption performed better compared to the DDRS. The number of simulation in favor of the swaption strategy was higher than the simulations in favor of the DDRS. The average swaption return was higher than the average DDRS return as well. Besides that, the average swaption return was positive as was predicted in the data description section of this document.

Variable	Base case
# simulations	4710
# swaption P&L > DDRS P&L	2890 (61.36%)
# swaption P&L < DDRS P&L	1820 (38.64%)
Average swaption premium	EUR 4.60
Average swaption P&L	EUR 2.84
Average DDRS P&L	EUR 2.51
Average PLD	EUR 0.33
Average PLD / Average swaption premium	7,17%
% positive PLD 1 months option maturities	33.33%
% positive PLD 60 months option maturities	93.88%
Lowest option maturity having positive PLD	23 months

***table 6.* PLD statistics -** The table shows the key figures of the base case simulations. As it was expected, the swaptions and DDRS have on average positive returns.

4.1.2.1 Swaption premium development

As discussed, the swaption premium at initiation of the simulations may have substantial effect on the swaption return and consequently on the simulation results. To visualize the difference between the magnitude in premium of short maturity swaptions and long maturity swaptions, the graph in *figure 19* has been created. As can be seen for maturities longer than 27 months, there are no expensive swaptions available in the sample.

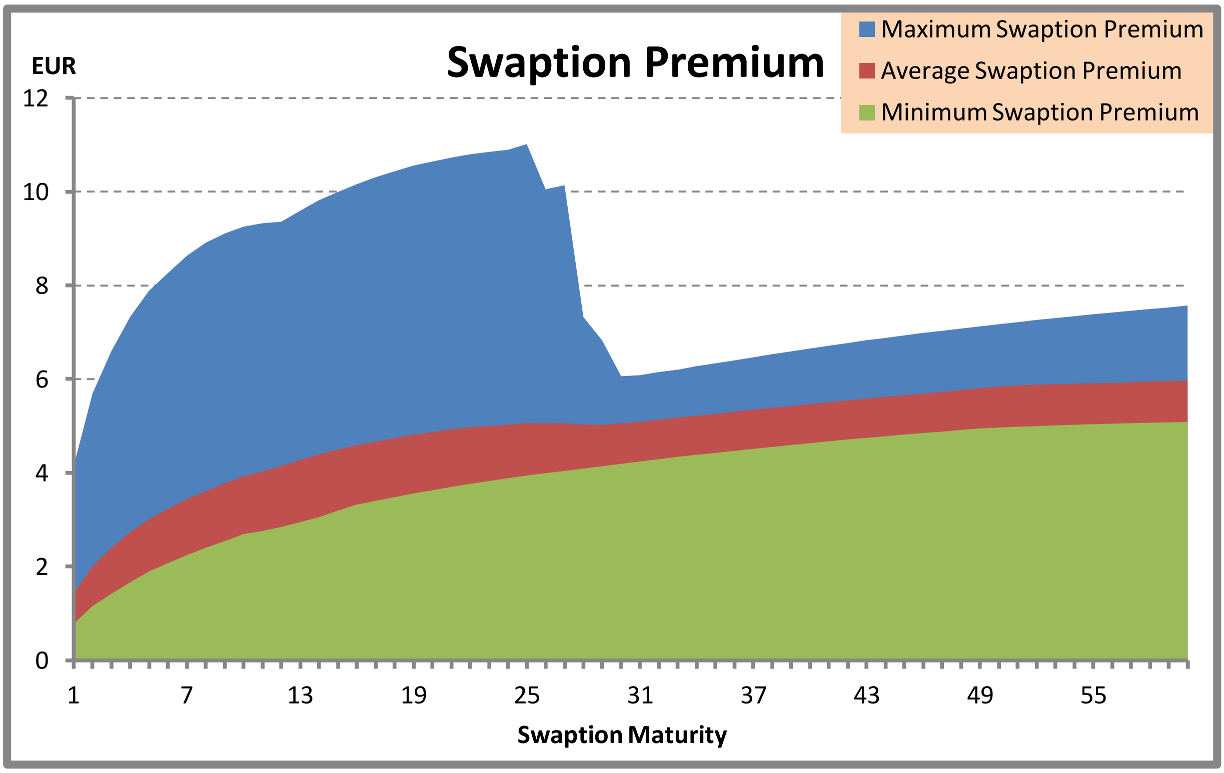

***figure 19.* Development swaption premium excluding high IV swaptions** – Swaption premium statistics, minimum, average and maximum swaption premium for simulations which are finished by using original market data.

The problem of missing expensive swaption has been tackled by adding interest rate and IV data after April 8th, 2011. This data has been generated by adding the development of the mentioned variables between September 29th, 2003 and September 29th, 2008 to the values after April 8th, 2011 day by day. This resulted in relatively flat development of the interest rate and the IV.

When more expensive swaptions are added to the data base, the maximum swaption premium shoot up to high levels as can be seen in *figure 20*. The addition of the generated data completes the data sample to reflect all possible combinations of short and long maturity swaptions and the difference in maximum swaption premium is obvious when both figures are compared. As the swaption strategy for long maturities performed only approximately EUR 1.50 better than the DDRS, the swaption premium development might explain that performance difference between the swaption strategy and the DDRS.

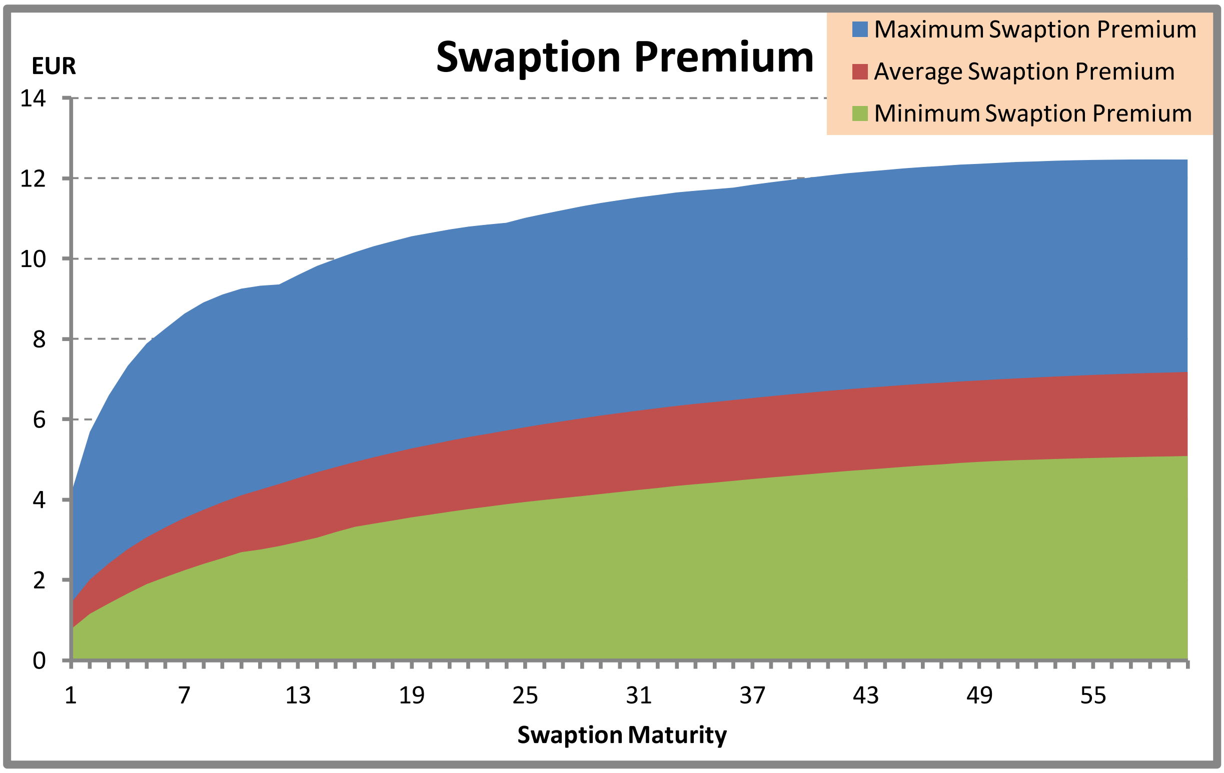

figure 20. **Development Swaption Premium excluding high IV swaptions** – Swaption premium statistics, minimum, average and maximum swaption premium for simulations which are finished by using extended market data.

Simulations are extended with the long maturity high IV swaptions based on the same parameters in the base case, For clarity, this is summarized in *table 7*.

Variable	Base case	Adding high IV long maturity swaptions
Moneyness	ATM	
Swap maturity	30 years	
Option maturity	1 - 60 months	
Start date simulations	2nd day of every month between April 2, 2002 and April 8, 2011	
swaption market spread	0% point IV	
Swap market spread	0 bps	
Rebalancing period for DDRS	1 day	

table 7. **Adding high IV long maturity swaptions** - This table shows the comparable simulation variables in the base case and the simulations with extended data.

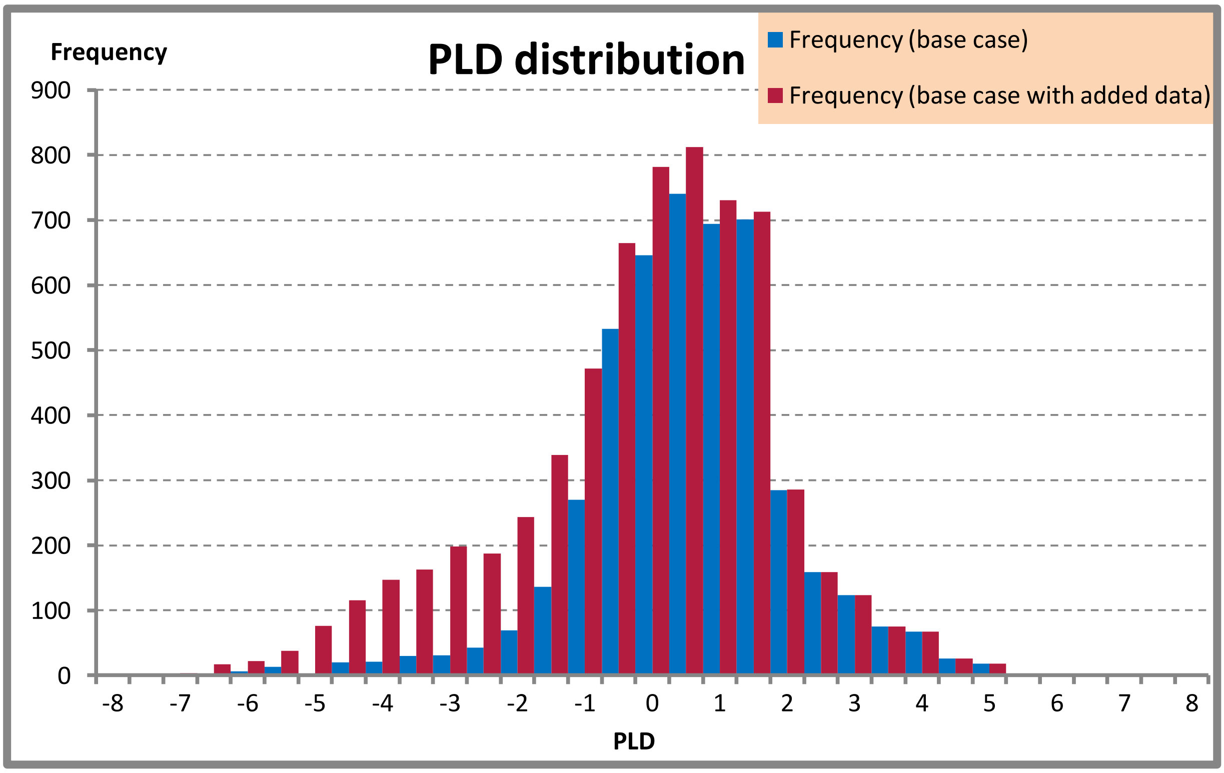

figure 21. **Comparison PLD distribution with and without expensive long maturity swaptions** - This figure shows the frequency distribution of the PLDs from simulations with original market data and from simulations with extended market data. The simulations in favor of the DDRS have increased much more than the simulations in favor of the swaptions strategy

After adding the simulations for the high IV swaptions, the conclusions changed substantially. As can be seen in *figure 21*, the frequencies for negative PLDs increased and the total distribution became more in favor of the DDRS.

The development of the average PLDs for different maturities is given in *figure 22*. Especially the long maturities have been affected by the added data. The expected difference between the swaption strategy and the DDRS changed in favor of the DDRS at all maturities between two months and 60 months. This means that expensive swaption premium affected the results very strongly in favor of the DDRS.

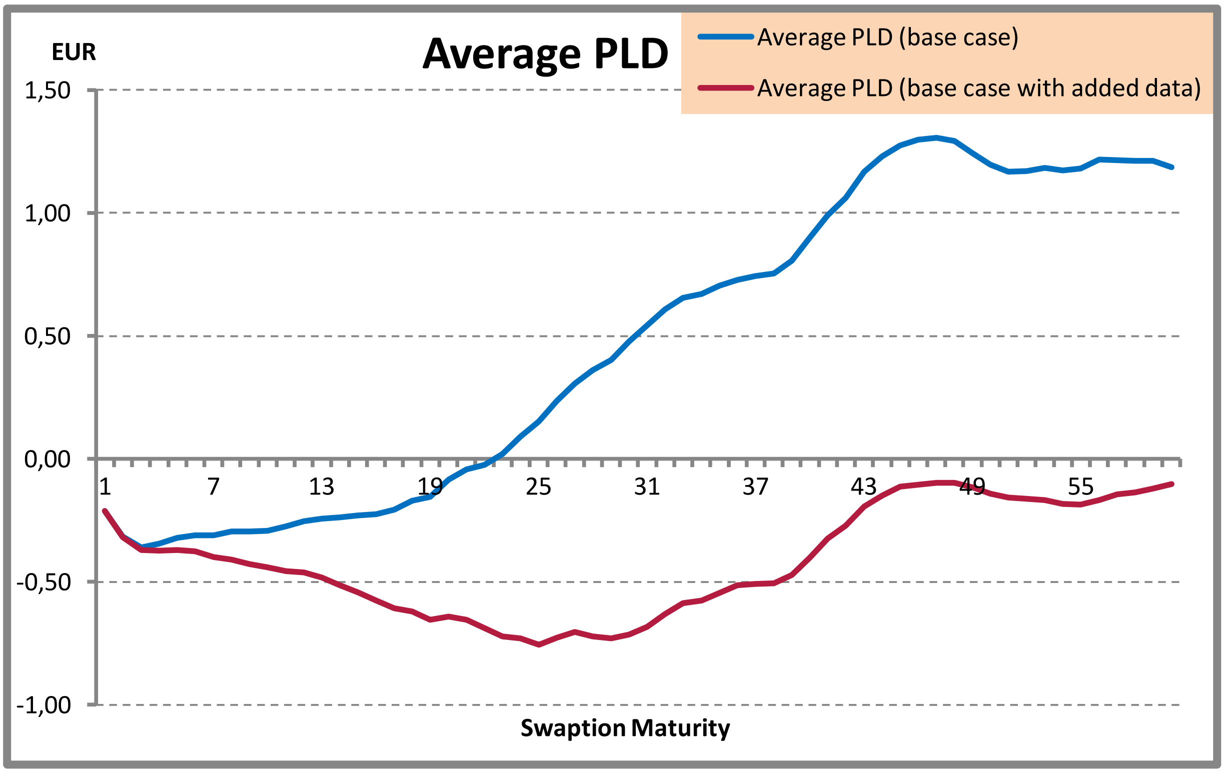

figure 22. **Average PLD's with and without expensive long maturity swaptions** – Average PLD's of simulation with original market data and simulation with extended data.

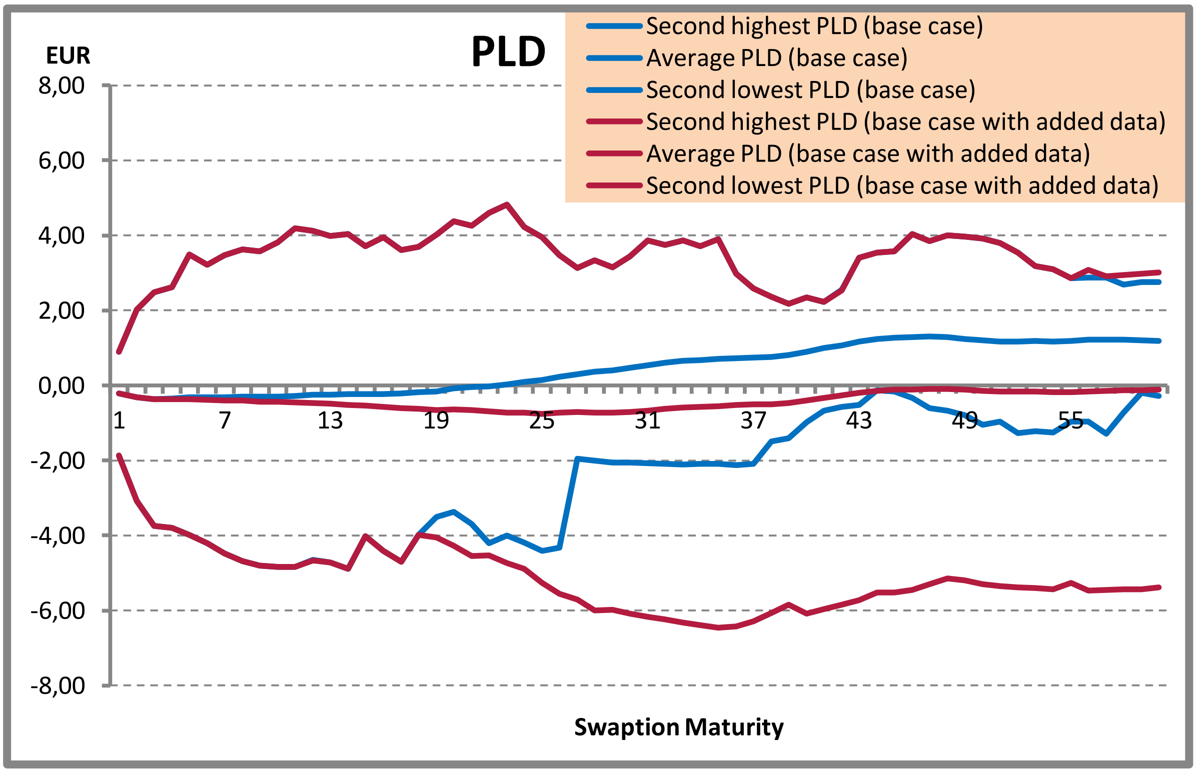

figure 23. **Average PLD, second highest and second lowest PLD** – Adding expensive long maturity swaptions to the sample made extreme observation in favor of the DDRS possible.

In *figure 23* the second highest and second lowest PLDs are compared. By adding long maturity high IV swaptions, the extreme observations in favor of the DDRS grew such that the second best simulations in favor of the DDRS for maturities higher than 28 months did not face a jump anymore. Instead of that, the second lowest PLDs developed more steadily.

In *table 8* the key figures can be seen. The key figures from the base case are put to make comparison easier. Most of the key figures developed in favor of the DDRS. While the average swaption premium increased by EUR 1.00, the relative efficiency of the swaption strategy decreased by EUR 0.75 and became negative meaning that the DDRS is on average more profitable than the swaption strategy. However, to base my simulations on real market data, the further analysis will be performed for the start dates and maturities which are presented in *table 4*.

Variable	Base case	Adding high IV long maturity swaptions
# simulations	4710	6480
# swaption P&L > DDRS P&L	2890 (61.36%)	3012 (46.48%)
# swaption P&L < DDRS P&L	1820 (38.64%)	3468 (53.52%)
Average swaption premium	EUR 4.60	EUR 5.60
Average swaption P&L	EUR 2.84	EUR 2.35
Average DDRS P&L	EUR 2.51	EUR 2.77
Average PLD	EUR 0.33	EUR -0.42
Average PLD / Average swaption premium	7,17%	-7,50%
% positive PLD 1 months option maturities	33.33% (36/108)	33.33% (36/108)
% positive PLD 60 months option maturities	93.88% (46/49)	58.33% (63/108)
Lowest option maturity having positive PLD	23 months	none

***table 8.* Simulation results including high IV long maturity swaptions** - The key figures of simulation with original market data are compared to the simulation results with extended market data.

All these results strongly support conclusion 2, that the premium to be paid for the swaption is of great influence to the question whether replication can add value. The higher the price, the more favorable it becomes to replicate the swaption.

4.1.3 Robustness check

To check whether the simulations led to robust conclusions, I need to make sure that some checks are completed. As the simulations were initiated every 2nd day of the month, the simulation result might be biased towards the start date or the finish date. One of the checks is to make sure that the choice to start all simulations at the beginning of the month doesn't have a big impact on the simulation results. If that is the case, performing one simulation every month will not be sufficient to draw conclusions.

To analyze the effect of the start date (and therefore also the specific end dates) on simulations, I compared the PLD results of different start dates. For efficiency purposes, I have simulated swaptions and DDRS with option maturities from 6 months up to 60 months with 6 months maturity steps starting at the 5th, 9th, 16th, 23th and the 30th of each month. The resulting average PLDs for different maturities have been compared to the base case simulations starting at the 2nd day of each month.

The average PLDs for the given maturities (1st column) initiated at the given start days of the months (1st row) are presented in *table 9*. The range for the average PLDs are low for the low maturities. However, for the longer maturities the difference of average PLD's increases considerably.

	2nd	5th	9th	16th	23rd	30th
6	-0,19	-0,22	-0,10	-0,09	-0,20	-0,19
12	-0,10	-0,08	0,03	0,02	-0,04	0,00
18	0,01	0,15	0,26	0,24	0,16	0,18
24	0,30	0,52	0,69	0,67	0,66	0,61
30	0,69	1,12	1,23	1,18	1,17	1,16
36	0,97	1,39	1,44	1,44	1,44	1,55
42	1,36	1,97	1,93	1,87	1,87	1,91
48	1,63	2,38	2,39	2,38	2,34	2,38
54	1,54	2,21	2,34	2,31	2,28	2,34
60	1,57	2,33	2,44	2,45	2,39	2,37

table 9. **Average PLDs at different initiation days -** Average PLDs in simulation results which are initiated at different days of the months.

Apparently, the initiation day (of the months) of the simulations with longer maturities does matter for the difference of the swaption P&L and the DDRS P&L. The difference between the different initiation days has been tested by the Wilcoxon Sign Rank Test (Sincich 1998). I chose a non parametric test, because the simulations are based on overlapping time periods. This test method is useful to test whether the difference of two samples is symmetric with zero median or not. If that is the case, the samples can be regarded as having an identical median. Otherwise the samples have different medians. By the mentioned test the H_0 is tested.

H_0: the compared samples have similar medians.

H_a: H_0 is not true.

The Wilcoxon Sign Rank Test confirms the results of the average PLDs. For the short maturities, the null hypothesis for similar medians is not rejected. However the null hypothesis for maturities between 30 months and 60 months are rejected. The p-values for the test are given in *table 10*.

	2nd	5th	9th	16th	23rd	30th
6	1	0.08*	0.74	0.37	0.75	0.83
12	1	0.27	0.97	0.84	0.82	0.89
18	1	0.74	0.29	0.26	0.44	0.33
24	1	0.6	0.27	0.24	0.41	0.31
30	1	0.09*	0.02**	0.02**	0.02**	0.01**
36	1	0.1*	0.01**	0.01**	0.00**	0.01**
42	1	0.00**	0.01**	0.02**	0.01**	0.01**
48	1	0.00**	0.00**	0.00**	0.00**	0.00**
54	1	0.00**	0.00**	0.00**	0.00**	0.00**
60	1	0.00**	0.00**	0.00**	0.00**	0.00**

table 10. **Wilcoxon sign rank test p-values** - The table includes p-value from the Wilcoxon Sign Rank Test. The p-values compare the medians of the PLDs of simulations at the given days (first row) of the months with simulation PLDs initiated at the second day of the months. P-values lower than 0.10 (marked by *) mean that the median of the simulation PLDs at the given day with the simulation PLDs at the second day of the months are statistically different at 10% significance level. P-values lower than 0.05 (marked by **) mean that the median of the simulation PLDs at the given day with the simulation PLDs at the second day of the months are statistically different at 5% significance level.

The given p-values are for comparison of the PLDs of simulations starting at the 2nd day of the month with the simulations starting at the day number given in the 1st row of the table. If the p-value is below 0.10, the null hypothesis can be rejected at 10% significance level, if the p-value is below 0.05, the null hypothesis can be rejected at 5% significance level, otherwise the null hypothesis cannot be rejected. As can be seen, the p-values for maturities between 6 months and 24 months are higher than 0.05. The p-values go below the 0.05 level for maturities between the 30 months and the 60 months simulations. Despite the given discrepancy of the long maturity simulations, the development of the PLD for different maturities still shows the same pattern. The low maturities are still in favor of the DDRS and the longer maturities are still in favor of the swaption strategy. Relying on these results, further research regarding sensitivity analyses will be based on the simulation which are initiated at the 2nd day of every month.

4.1.4 Conclusions

Based on the analysis of the results so far, several conclusions can be drawn:

Conclusion 1: Stable periods result in favor of the DDRS.

Conclusion 2: Unstable periods with high IV at inception also favors the DDRS.

The swaption premium has substantial effect on the comparison. The swaptions lost their relative efficiency when they are purchased at high IV.

Conclusion 3: In circumstances of decreasing interest rates the swaption performed better.

Conclusion 4: For lower maturity swaptions, delta replication offers better possibilities than for higher maturity swaptions.

The relative efficiency of the compared strategies depend on the maturity of the simulations. The DDRS is more efficient for the short maturity simulations. For the long maturities the swaptions are more efficient. The short maturity swaption are thus relatively expensive to purchase. Instead, the delta replication can be performed.

A bias towards the initiation day of the simulations has been noted. While the long maturity simulations showed a discrepancy in average PLDs for different initiation days, this did not change the general pattern of the relative efficiency of one strategy compared to the other strategy.

Note that all these conclusions so far are based upon the base case, where especially the 0 trading costs assumption can be disputable. Further results where this assumption is relaxed follows in the chapter ahead. In further analysis, the expensive swaptions are excluded.

4.2 Adding trading costs

4.2.1 Trading in normal times

The parameters for this simulation are shown in *table 11*.

Variable	Base case	Adding trading cost
Moneyness	ATM	
Swap maturity	30 years	
Option maturity	1 - 60 months	
Start date simulations	2nd day of every month between April 2, 2002 and April 8, 2011	
swaption market spread	0% point IV	0.5% point IV
Swap market spread	0 bps	0.5 bps
Rebalancing period	1 day	1 day

table 11. **Simulation variables including trading costs** - This table shows the simulation variables for the base case simulations and the simulations with trading costs for swaptions (0.5% point IV) and DDRS (0.5 bps).

In this simulation, the trading costs for swaptions and swaps were included. The swap market spread was set at 0.5 bps. The market spread of the swaption was set at 0.5% point in IV terms. A half of the spread is equal to the trading costs. For swaptions, the trading costs incurred once, at inception of the swaption. For swaps, some trading costs are incurred each time the position is rebalanced towards the prevailing delta of the swaption.

The distribution of the PLD for all simulations is given in *figure 24*. The blue bars show the frequency distribution in the base case simulations, the yellow bars show the distribution of the simulations including trading costs. Comparison shows that the distribution has moved to the right, meaning that the swaption strategy has become more attractive compared to the previous analysis. This means that the swaption trading costs are lower compared to the DDRS trading costs.

The trading costs in the DDRS has deteriorated the DDRS return more heavily than the swaption trading costs have deteriorated the swaption return. The average one month swaption trading cost was EUR 0.02. The trading cost increased gradually up to EUR 0.13 for 60 months simulations. The DDRS average trading cost was EUR 0.09 for one month maturities. This average went up to EUR 0.52 for the 60 months simulations. For any maturity the swap trading costs exceeded the swaption trading costs.

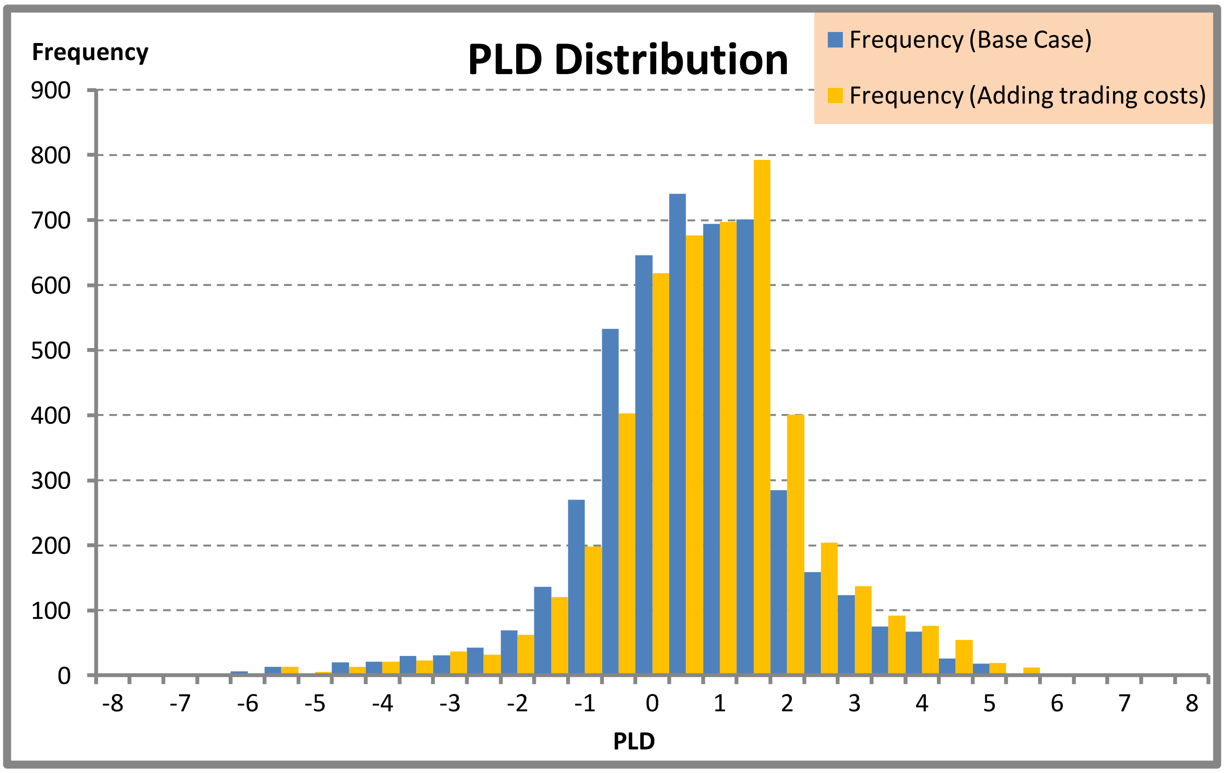

figure 24. **PLD distribution** - Comparison of the PLD distributions of simulations with and without trading costs.

The simulation results are presented in *table 12*. The number of simulations in favor of the swaption strategy increased to 67.18% from 61.36% in the base case simulations. The average P&L of the swaption strategy including trading costs is EUR 2.75 compared to EUR 2.84 in the base case. The average P&L of the DDRS diminished to EUR 2.20 from EUR 2.51 after including the trading costs. Compared to the base case, the DDRS performance decreased by EUR 0.31, while the swaption performance decreased by EUR 0.09. This leads to an increase of the PLD to EUR 0.55 from EUR 0.33, an average gain of EUR 0.22 for the swaption strategy relative to the DDRS.

As the DDRS costs are *linear* to the swap market spread, the average DDRS costs will decrease to EUR 0.09 if the swap market spread is equal to 0.15 bps. In that case the swaption trading costs and the DDRS trading costs will be equal and the relative efficiency of one strategy compared to the other strategy will not be affected by the introduction of trading costs in this paragraph. However the swaption market spread of 0.5 % points IV in combination with the swap market spread of 0.5 bps is chosen because it is the best reflection of actual trading costs. In further analysis, this ratio will be maintained.

Variable	Base case	Adding trading cost
# simulations	4710	
# swaption P&L > DDRS P&L	2890 (61.36%)	3164 (67.18%)
# swaption P&L < DDRS P&L	1820 (38.64%)	1546 (32.82%)
Average swaption premium	EUR 4.60	EUR 4.70
Average swaption P&L	EUR 2.84	EUR 2.75
Average DDRS P&L	EUR 2.51	EUR 2.20
Average PLD	EUR 0.33	EUR 0.55
Average PLD / Average swaption premium	7.17 %	11.70%
% positive PLD 1 months option maturities	33.33% (36/108)	46.30% (50/108)
% positive PLD 60 months option maturities	93.88% (46/49)	100% (49/49)
Lowest option maturity having positive PLD	23 months	18 months

table 12. **PLD statistics** – Adding trading costs to the base case resulted in favor of the swaptions due to the trading costs of the DDRS which are higher than swaption trading costs.

The development of the average PLDs are shown in *figure 25*. The average PLD line shows the same pattern as in the base case, however at a higher level. The average PLD turned positive for maturities higher than 18 months compared to 23 months in the base case. For the 1 month swaptions, 46.30% of the simulation runs showed that the swaption performs better. For the 60 months swaptions this percentage went up to 100%. In the base case these percentages were 33.33% and 93.88%. Overall the swaption performs relatively better than DDRS by adding trading costs.

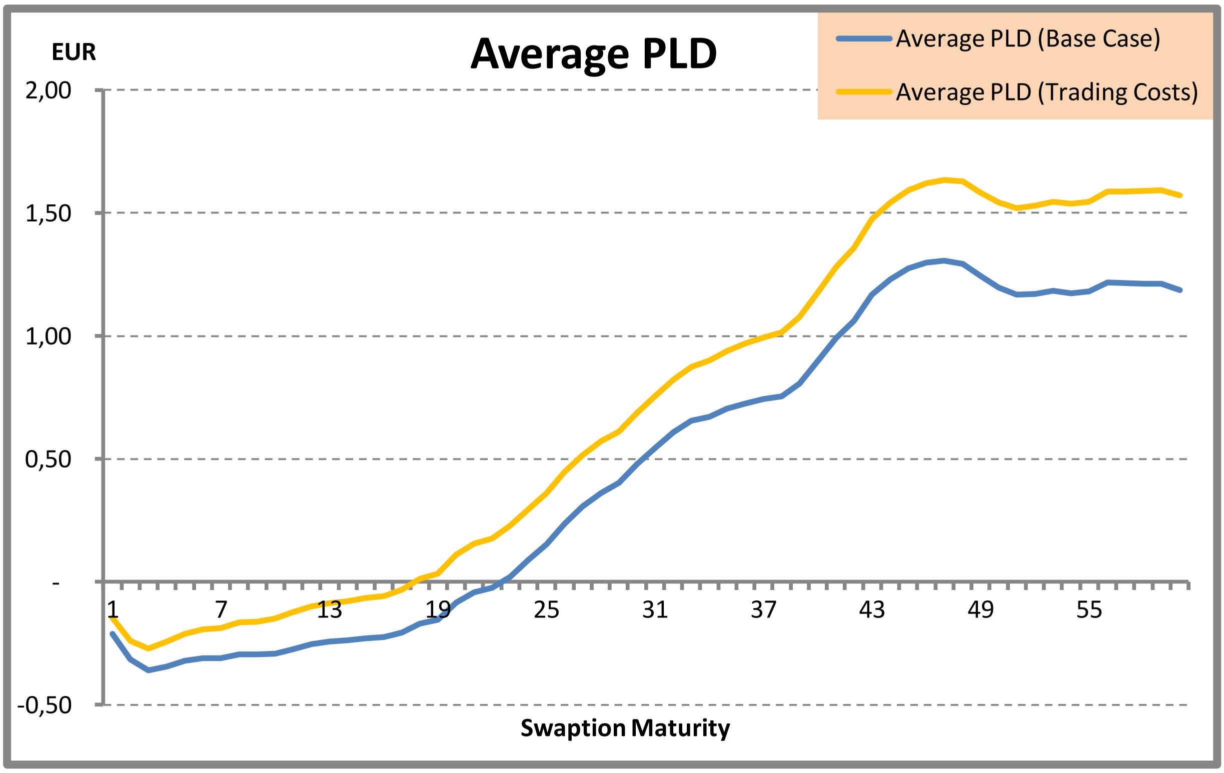

figure 25. **Average PLDs (base case) and average PLDs (including trading costs)** - The average PLDs show similar pattern. However including trading costs shifted up the development of the average PLDs.

In *figure 26* the second highest and the second lowest values for PLDs are shown. The same PLDs from the base case is put in the graph to make comparison possible. The same pattern for the average, the second highest and the second lowest PLDs are observed as in the base case. The lines only shifted up by the average costs differences. The increase of the mentioned key figures of the PLDs is higher for the long maturities compared to the short maturities.

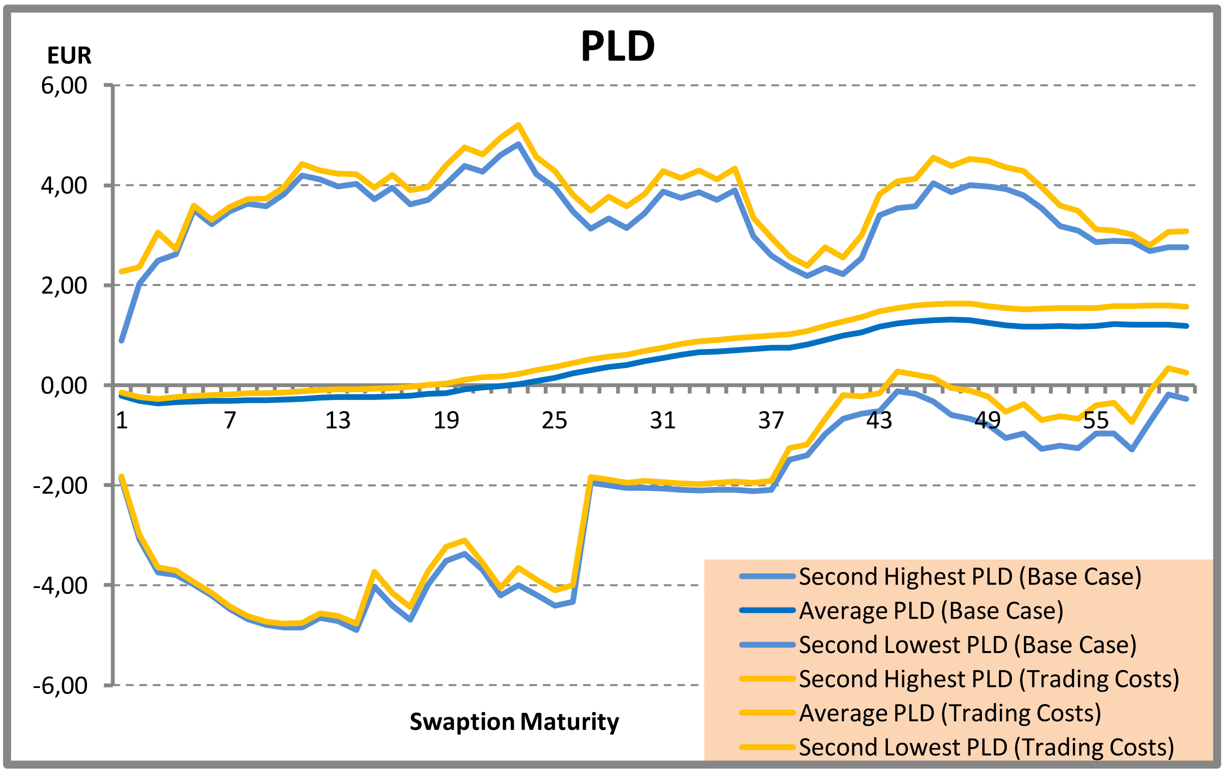

figure 26. **Average PLD, Maximum PLD, Minimum PLD -** Comparison of the second highest PLD and the second lowest PLD for different maturities with and without trading costs. Adding trading costs increased second highest and the second lowest PLD at every maturity.

4.2.2 Trading costs in stress

The analysis as it is performed in the previous paragraphs has been performed for different levels of trading costs. *Table 13* shows the variables used in these simulations.

Variable	Base case	Adding trading cost (1)	Adding trading cost (2)	Adding trading cost (3)	Adding trading cost (4)
Moneyness	ATM				
Swap maturity	30 years				
Option maturity	1 - 60 months				
Start date simulations	2nd day of every month between April 2, 2002 and April 8, 2011				
swaption market spread	0% point IV	0.5% point IV	1.0% point IV	1.5% point IV	2.0% point IV
Swap market spread	0 bps	0.5 bps	1.0 bps	1.5 bps	2.0 bps
Rebalancing period for DDRS	1 day				

table 13. **Simulation variables for various trading costs** - The input variables for simulations with trading costs. The trading costs increased for swaptions (0.5% point IV per step) and the swaps (0.5 bps per step).

Table 14 includes the results for different trading costs. The numbers show that the DDRS performance is strongly depending on the trading costs. For every additional increase of the swap market spread by 0.5 bps, the DDRS performance worsens about EUR 0.31 per simulation. The increase of the swaption market spread for every 0.5% IV points, causes the swaption premium to go up by about EUR 0.09. As the swaption pay off doesn't change by changing swaption premium, the swaption performance worsens by the same amount.

The trading costs for the swaps and the swaptions together cause the average PLD to go up by about EUR 0.22 for every additional increase of the market spread by 0.5 bps in the swap market and 0.5% IV points in the swaption market. This makes the swaption strategy relatively more attractive if the trading costs are high. Hereby the assumption is made that the swaption market spread and the swap market spread in stress are multiplications of the spreads in the simulations with trading costs in normal times.

Variable	Base case	Adding trading cost (1)	Adding trading cost (2)	Adding trading cost (3)	Adding trading cost (4)
# simulations	4710				
# swaption P&L > DDRS P&L	2890 (61.36%)	3164 (67.18%)	3405 (72.29%)	3605 (76.53%)	3840 (81.53%)
# swaption P&L < DDRS P&L	1820 (38.64%)	1546 (32.82%)	1305 (27.71%)	1105 (23.46%)	870 (18.47%)
Average swaption premium	EUR 4.60	EUR 4.70	EUR 4.80	EUR 4.88	EUR 4.97
Average swaption P&L	EUR 2.84	EUR 2.75	EUR 2.64	EUR 2.56	EUR 2.47
Average DDRS P&L	EUR 2.51	EUR 2.20	EUR 1.89	EUR 1.58	EUR 1.28
Average PLD	EUR 0.33	EUR 0.55	EUR 0.75	EUR 0.98	EUR 1.19
Average PLD / Average swaption premium	7.17%	11.70%	15.87%	20.08%	23.94%
% positive PLD 1 months option maturities	33.33% (36/108)	46.30% (50/108)	53.70% (58/108)	62.96% (68/108)	70.37% (76/108)
% positive PLD 60 months option maturities	93.88% (46/49)	100% (49/49)	100% (49/49)	100% (49/49)	100% (49/49)
Lowest option maturity having positive PLD	23 months	18 months	11 months	5 months	1 months

***table 14.* Simulation results for various trading costs** - The table shows the key figures of the simulation results for increasing trading costs.

4.2.3 Conclusions

Including trading costs decreased the performance of both strategies. For the given combinations of cost parameters, the swaption strategy became relatively more attractive. The gap between the average swaption P&L and the DDRS P&L increased from 7.17% in the base case to 23.94% in the simulation case with swap spread equal to 2.0 bps and swaption spread equal to 2.0% IV point. If the trading costs are increased, more maturities have positive average PLD. Overall, the following conclusion can be drawn:

Conclusion 5: Trading costs decrease the relative attractiveness of a replicating strategy.

4.3 Rebalancing frequency

The analysis of the trading costs showed that the costs can have substantial effect on the efficiency of the DDRS. Traders of pension funds are price takers in the market and cannot change the bid-offer spread in the market. If one is interested in saving trading costs, lowering the rebalancing frequency is therefore the only possibility. A lower rebalancing frequency will however result in higher hedging error. Whether the gain from lower trading costs offsets the increased hedging error is investigated in this paragraph, where simulation results for different rebalancing periods will be shown.

4.3.1 Weekly

<table>
<tr><th>Variable</th><th>Base case</th><th>Adding trading cost</th><th>Weekly rebalancing</th></tr>
<tr><td>Moneyness</td><td colspan="3">ATM</td></tr>
<tr><td>Swap maturity</td><td colspan="3">30 years</td></tr>
<tr><td>Option maturity</td><td colspan="3">1 - 60 months</td></tr>
<tr><td>Start date simulations</td><td colspan="3">2nd day of every month between April 2, 2002 and April 8, 2011</td></tr>
<tr><td>swaption market spread</td><td>0% point IV</td><td colspan="2">0.5% point IV</td></tr>
<tr><td>Swap market spread</td><td>0 bps</td><td colspan="2">0.5 bps</td></tr>
<tr><td>Rebalancing period for DDRS</td><td colspan="2">1 day</td><td>1 week</td></tr>
</table>

***table 15.* Weekly rebalancing including costs** - The table shows a comparison of the simulation variables for the base case simulation, the simulations with trading costs and the weekly rebalancing simulations.

In the first place the rebalancing period has been increased to one week according to *table 15*. The results are compared with the results of the base case including 0.5 bps trading costs, as decreasing the rebalancing frequency only makes sense when it is compared to simulations with trading costs.

The resulting PLD distribution is given in *figure 27*. We observe that the frequency peak around the average is lower now. The distribution of the PLDs became more widespread, meaning that more extreme observations in favor of the swaptions strategy and the DDRS have become possible by lowering the rebalancing frequency. Especially the upper tail profited from lower rebalancing frequency, meaning that the swaptions profited from this change of the rebalancing frequency. This means that trading cost savings in the DDRS due to lower rebalancing frequency are less than the additional costs due to the higher hedging error. As the relative DDRS performance is limited to the swaption premium, more extremely positive PLDs are observed. Decreasing rebalancing frequency from daily to weekly resulted in favor of the swaption strategy.

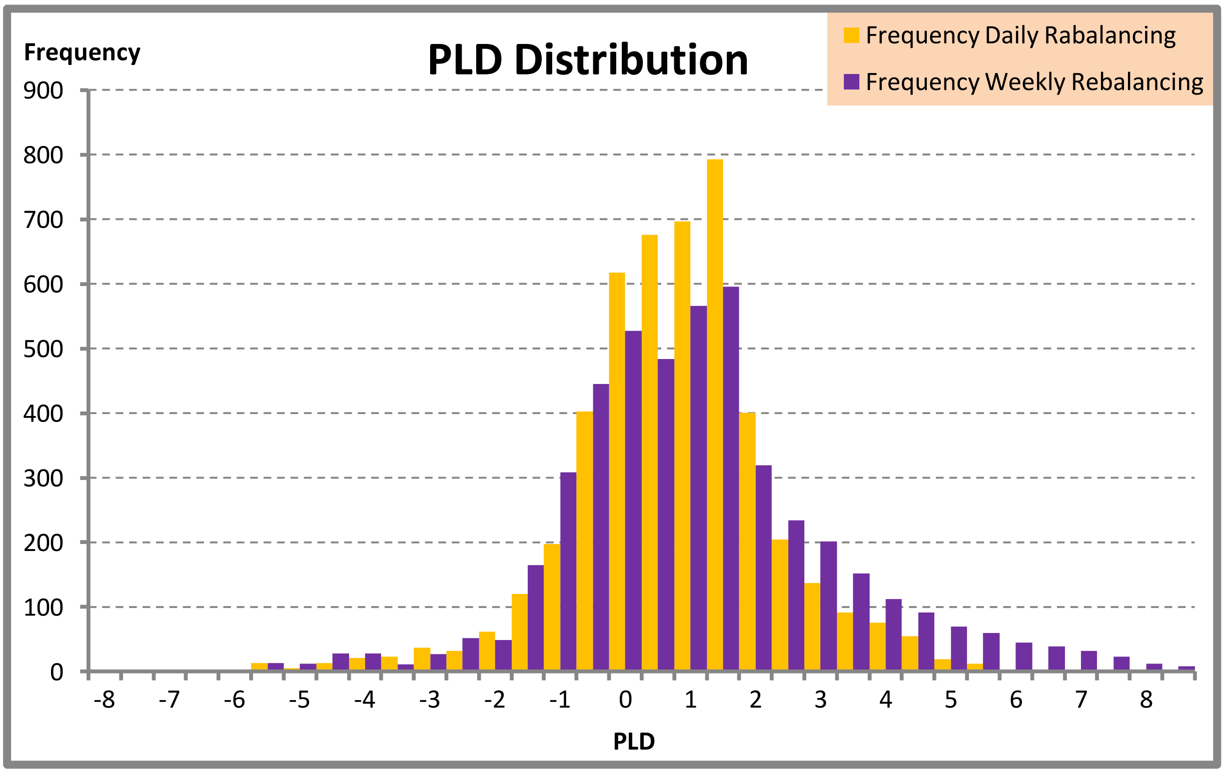

figure 27. **PLD distribution for weekly rebalancing -** The figure shows a comparison of the PLD distribution of simulations which are rebalanced daily and simulations which are rebalanced weekly. In the weekly rebalancing simulations, more widespread PLDs are observed. Extreme results in favor of the swaptions are observed more frequently than extreme results in favor of the DDRS.

The key figures are given in *table 16*. The average PLD increased to EUR 0.84 from EUR 0.55 in the simulations with daily rebalancing including trading costs. The key figures show that slightly less number of simulations are in favor of the swaption strategy. However the weekly rebalancing simulations led on average to better performance of the swaption strategy. This is caused by the outliers on the upside. Remarkable is the decrease of the lowest maturity which has positive PLD from 18 months maturity to 15 months maturity.

Variable	Base case	Adding trading cost	Weekly rebalancing
# simulations	4710		
# swaption P&L > DDRS P&L	2890 (61.36%)	3164 (67.18%)	3045 (64.65%)
# swaption P&L < DDRS P&L	1820 (38.64%)	1546 (32.82%)	1665 (35.35%)
Average swaption premium	EUR 4.60	EUR 4.70	EUR 4.70
Average swaption P&L	EUR 2.84	EUR 2.75	EUR 2.75
Average DDRS P&L	EUR 2.51	EUR 2.20	EUR 1.90
Average PLD	EUR 0.33	EUR 0.55	EUR 0.85
Average PLD / Average swaption premium	7.17%	11.70%	18.09%
% positive PLD 1 months option maturities	33.33% (36/108)	46.30% (50/108)	38.89% (42/108)
% positive PLD 60 months option maturities	93.88% (46/49)	100% (49/49)	100% (49/49)
Lowest option maturity having positive PLD	23 months	18 months	15 months

table 16. **PLD statistics -** The table shows the key figures of the base case simulation, simulation in which trading costs are taken into account and simulations which are rebalanced weekly.

In *figure 28* the development of the average PLD is presented. The PLD for the long maturities increased substantially compared to the daily simulations. For lower rebalancing frequency, it can be said that the longer the simulation maturity, the higher the average PLD increase. In the long run the additional hedging errors stack up to high levels, in the short run the additional hedging errors are low compared to savings of the trading costs.

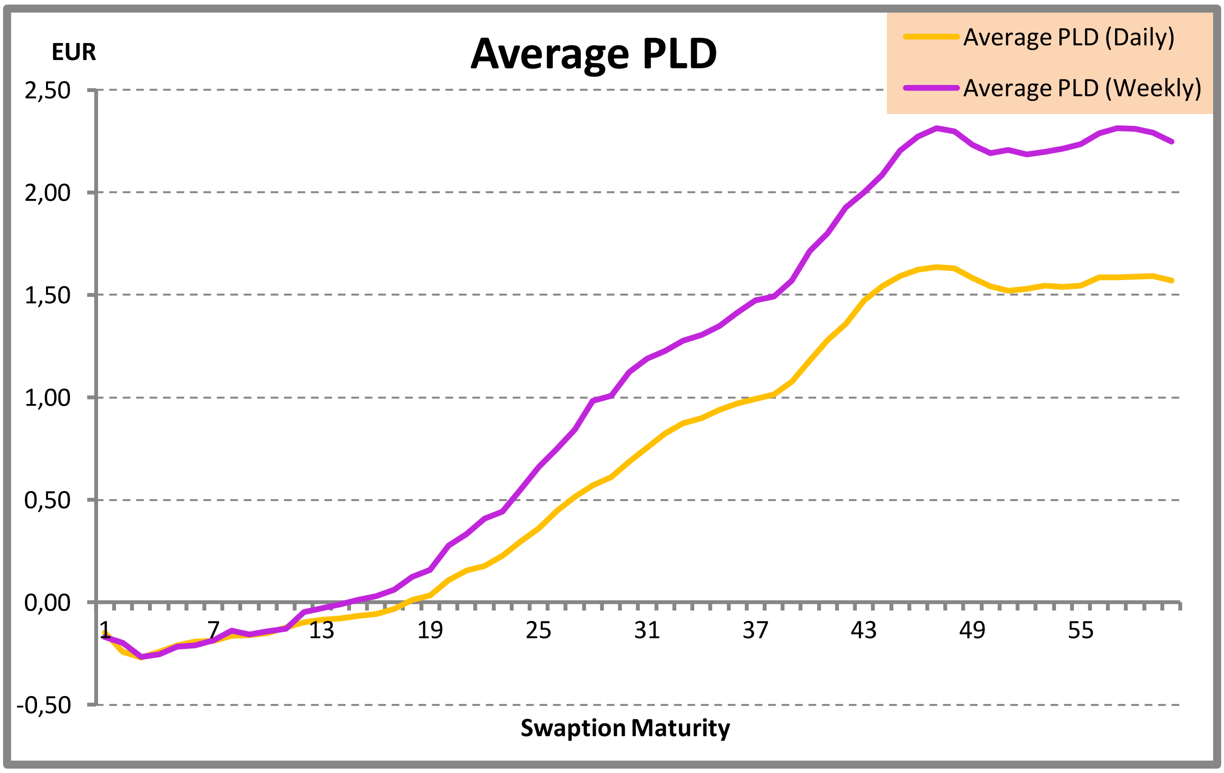

figure 28. **Average PLDs** - The comparison of the daily rebalancing with weekly rebalancing simulations shows the move of the simulations in favor of the swaption strategy.

Figure 29 shows the second highest PLDs and the second lowest PLDs. The lower bound of weekly rebalancing simulations is nearly similar to the simulations with daily rebalancing. However the upper bound increased for most of the maturities. This is due to the fact that the upper bound is not limited, while the lower bound is limited to the swaption premium. Again, it's made clear that the weekly rebalancing portfolio has higher range of PLDs compared to the daily rebalancing. Less frequent trading leads to more extreme results.

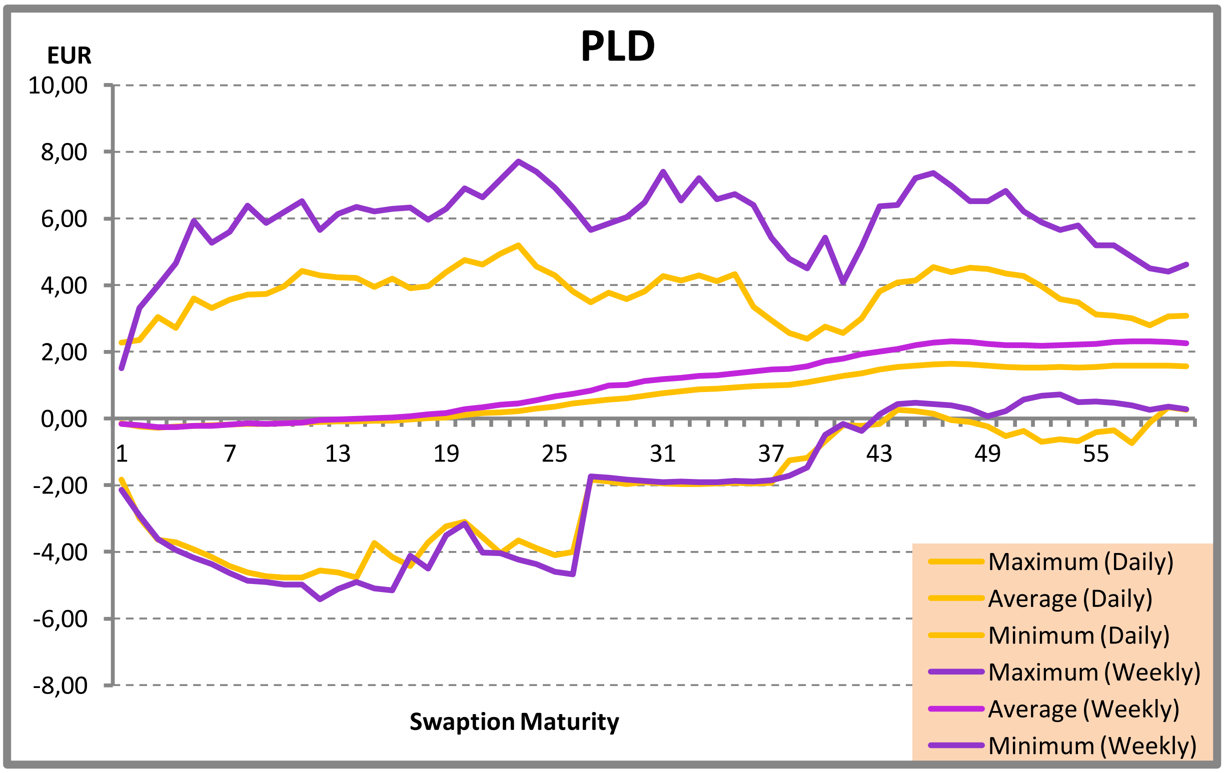

figure 29. **Average PLDs, second highest PLDs, second lowest PLDs** – Weekly rebalancing made extreme observations in favor of the swaption possible. Outliers in favor of the DDRS are not affected.

4.3.2 More rebalancing periods

Variable	Base case	Including trading costs	Rabalancing frequency				
			weekly	2 weekly	4 weekly	8 weekly	At initiation
Swap maturity	30 years						
Option maturity	1 - 60 months						
Start date simulations	2nd day of every month between April 2, 2002 and April 8, 2011						
Swaption market spread	0% point IV	0.5% point IV					
Swap market spread	0 bps	0.5 bps					
Rebalancing period for DDRS	1 day		1 week	2 weeks	4 weeks	8 weeks	once at initiation

table 17. **Different rebalancing periods** - The table shows the simulation variables for different rebalancing frequencies.

The set of parameters is given in *table 17*. The rebalancing period has been increased gradually from 1 week to 2, 4 and 8 weeks and finally to the ultimate situation where no rebalancing takes place after the initial set up of the strategy. For these simulations the trading cost parameter was set at 0.5 bps and the swaption market spread was set at 0.5% IV point.

The development of the key figures are shown in *table 18*. The figures show a *non linear* development for increasing rebalancing period. In general, it can be stated that the number of simulations in favor of the DDRS increased for lower rebalancing frequencies. Exceptionally, in the steps from the four weekly rebalancing simulations to eight weekly rebalancing simulations, the number of simulations in favor of the DDRS decreased. In the 'No Rebalancing' simulations, the mentioned number increases again to its maximum level of 2644 in the given set of simulations.

Variable	Base case	Including trading costs	Rabalancing frequency				
			weekly	2 weekly	4 weekly	8 weekly	At initiation
# simulations	4710						
# swaption P&L > DDRS P&L	2890 (61.36%)	3164 (67.18%)	3045 (64.65%)	2889 (61.34%)	2622 (55.67%)	2852 (60.55%)	2066 (43.86%)
# swaption P&L < DDRS P&L	1820 (38.64%)	1546 (32.82%)	1665 (35.35%)	1821 (38.66%)	2088 (44.33%)	1858 (39.45%)	2644 (56.14%)
Average swaption premium	EUR 4.60	EUR 4.70	EUR 4.70	EUR 4.70	EUR 4.70	EUR 4.70	EUR 4.70
Average swaption P&L	EUR 2.84	EUR 2.75	EUR 2.75	EUR 2.75	EUR 2.75	EUR 2.75	EUR 2.75
Average DDRS P&L	EUR 2.51	EUR 2.20	EUR 1.90	EUR 1.95	EUR 2.41	EUR 2.30	EUR 2.73
Average PLD	EUR 0.33	EUR 0.55	EUR 0.85	EUR 0.80	EUR 0.34	EUR 0.45	EUR 0.02
Average PLD / Average swaption premium	7.17%	11.70%	18.09%	17.02%	7.23%	9.57%	0.43%
% positive PLD 1 months option maturities	33.33% (36/108)	46.30% (50/108)	38.89% (42/108)	68.52% (74/108)	30.56% (33/108)	33.33% (36/108)	33.33% (36/108)
% positive PLD 60 months option maturities	93.88% (46/49)	100% (49/49)	100% (49/49)	100% (49/49)	85.71% (42/49)	89.80% (44/49)	42.85% (21/49)
Lowest option maturity having positive PLD	23 months	18 months	15 months	16 months	23 months	21 months	23 months

***table 18.* PLD statistics**[9] - The key figures for different rebalancing frequencies are presented in this table. Increasing the rebalancing period of the DDRS changed the simulation results. Increase of the rebalancing period to one week made the swaption strategy more efficient. Further increase to two weeks was a move in favor of the DDRS. Increasing the rebalancing period to four weeks was again in favor of the DDRS. Increasing the rebalancing period to eight weeks was a step in favor of the swaptions. Rebalancing once at inception made the DDRS as efficient as the swaption strategy.

More important is the development of the average PLDs. The average relative efficiency of the swaption strategy over the DDRS showed increase in the first step from daily rebalancing to weekly rebalancing. When the rebalancing period was increased further to two weeks, the PLD decreased

[9] In the "No Rebalancing" simulations the PLD turns negative for maturities 39 months up to 60 months.

slightly. For rebalancing periods longer than two week, the PLD declined considerably. While the PLD of the four weekly rebalancing period was about one third of the average PLD of simulations with two weekly rebalancing period, in the eight weekly rebalancing simulations a small increase is observed. In the last set of simulations for which only two rebalancing moments exist, the PLD diminished to EUR 0.02. This means that on expectation both strategies have (almost) the same return.

Another exceptional development is the turning point of the PLD from negative to positive numbers. In all simulations until now the simulations showed that DDRS is more efficient for the short maturities and the swaption strategy is performing better for the longer maturity simulations. Simulations with no intermediate rebalancing moments showed however that the average PLD had a hump shaped development. For maturities shorter than 23 months and longer than 39 months the PLD was negative, meaning that the DDRS was performing better. The maturities in between had positive average PLD.

Variations in the rebalancing period provide information about the development of the hedging error. By increasing the rebalancing period, the trading costs of the DDRS decreased. However, this doesn't mean that the DDRS became more efficient. Due to the hedging error, in some rebalancing steps the DDRS became less efficient. As the hedging error depends on the specific path of the underlying, the costs due to hedging error can vary a lot.

The increase of the hedging error is easy to explain. As the rebalancing takes place infrequently, the delta and the market value of the swaption can change a lot in between the rebalancing moments. Due to this feature, less trading will lead to higher hedging error of the DDRS. The effect on the relative efficiency of the DDRS is uncertain in that case.

On beforehand, one would have expected the hedging error to increase steadily as the rebalancing period increases. The fact that this is not the case is caused by the periodicity of interest rates, and highly depends on the exact period of the data sample. If in a certain data sample, the average time for interest rates to (partly) recover from a large decrease is about four weeks, it can be shown that such a rebalancing period is in fact, ex-post, the optimal rebalancing period in order to minimize the PLD and hedging error. Due to this match, unnecessary trades during the extreme swings in the progress of the interest rates are avoided. In that case, the relative efficiency of the DDRS increases for two reasons, lower trading costs and lower hedging error. In the simulations which are discussed in this paragraph, this happened three times. The DDRS return of the two-weekly rebalancing simulations was better compared to weekly rebalancing. The DDRS return of the four-weekly rebalancing simulations was better than the two-weekly rebalancing simulations. The step from eight-weekly simulations to no rebalancing improved the relative DDRS return as well. In those steps of rebalancing periods, the matches between the rebalancing periods and the interest rates became more efficient. In the most extreme case, the DDRS became as efficient as the swaption strategy.

4.3.3 Conclusions

Although this analysis provides a lot of insight ex-post in the way rebalancing impacts the eventual result and relative efficiency, it is difficult to draw hard conclusions regarding the 'optimal' rebalancing period. This partly depends on the periodicity of the interest rate cycle, which is not well known in advance. It also depends on the risk aversion that is relevant for the strategy: although longer rebalancing periods might improve the expected result from a replication strategy, it will also increase the maximum possible deviation from the value development of the swaption.

The DDRS became less efficient when the rebalancing period was increased from one day to one week. However this development reverted when the rebalancing period was increased to two weeks or higher. In the extreme case of no intermediate rebalancing, the DDRS became as efficient as the swaption strategy was. The worst rebalancing period in favor of the DDRS lies between one week and two weeks.

4.4 Scenario analysis

To conclude the research, I look at specific scenario's. This provides additional insight in the dynamics of a DDRS, and the specific moments that can prove to be a risk or an opportunity for such a strategy. In these scenarios different combinations of underlying interest rate development and IV development are used.

4.4.1 Interest rate increase, IV decrease

The first scenario is a combination of interest rate increase and IV decrease. This combination has been realized during the crisis after the lowest level of the 30 years interest rate (2.66%) was reached at December 3rd, 2008. In the period between December 3rd, 2008 and July 6th, 2009 the forward swap rate increased to 4.04% from 2.79%, while the IV decreased to 18.85% from 57.43%. To show the characteristics in this period a six months swaption was simulated in which the DDRS is rebalanced daily with taking into account trading costs. In this specific simulation the swaption expired worthless and lost the total initial premium of EUR 9.16. The DDRS net loss stuck at EUR 5.99.

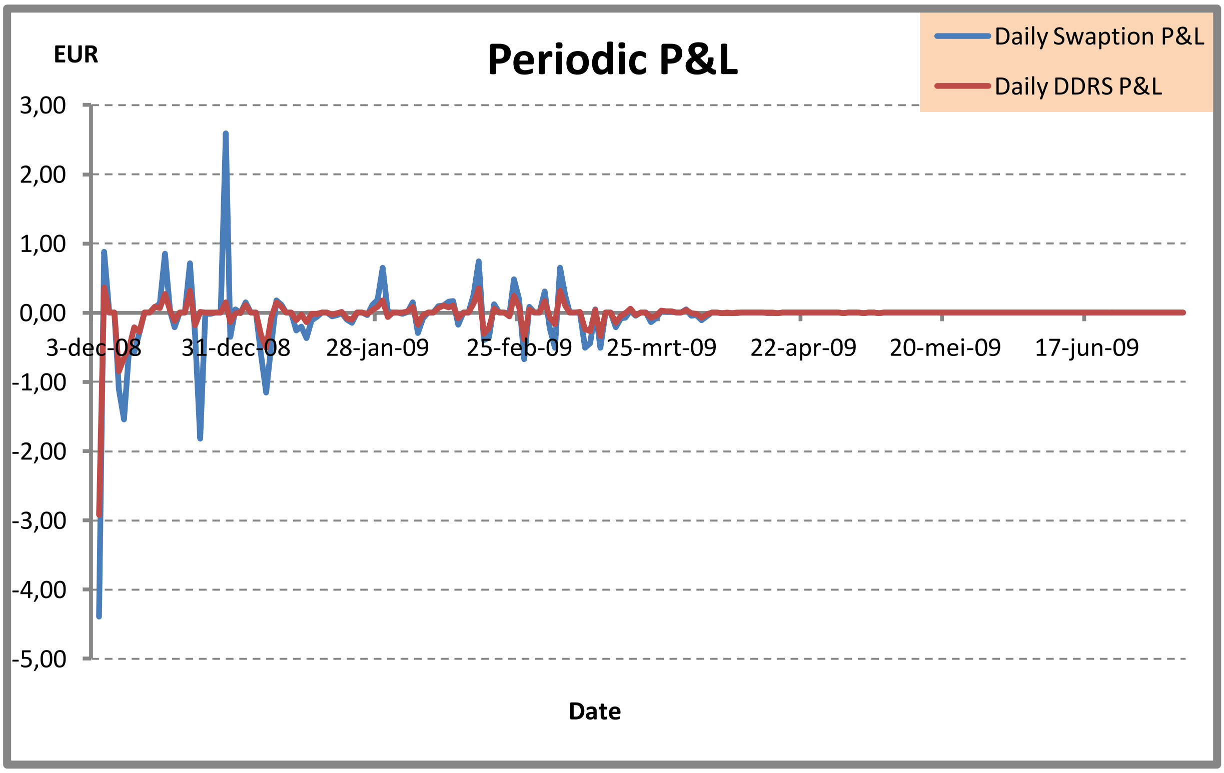

***figure 30.* Development daily P&L** - In the figure, the P&L development of the swaption strategy and the DDRS is plotted. The swaption daily P&L is more volatile than the DDRS P&L.

In *figure 30* can be seen that the periodic swaption P&L was more volatile than the periodic DDRS P&L. Apparently, the periodical swaption P&L reacted stronger to changes of the underlying swap rate compared to the DDRS. This is caused by the strong negative correlation (-0.89) between the interest rates and the IV. Increasing interest rates caused the swaption strategy to lose its initial premium at expiration. As the total P&L was negative for both strategies, the total swaption loss was higher than the total DDRS loss.

As the underlying interest rate moved to a higher level during the simulation period, the swaption became OTM and its value reacted ever less strong to changes of the underlying interest rate. This is observed in the graph, especially from March 25th, 2009 until expiration.

4.4.2 Interest rate decrease, IV increase

The scenario in which the interest rate decreased and the IV increased took place in the period prior to December 3rd, 2008. At July 3rd, 2008 the forward swap rate was at 4.80%. The IV was 15.13% for the five months swaptions. The swap rate decreased to 2.80% and the IV increased to 138.04% at December 3rd, 2008. In this simulation the swaption P&L was EUR 35.22, while the DDRS net P&L became EUR 33.42.

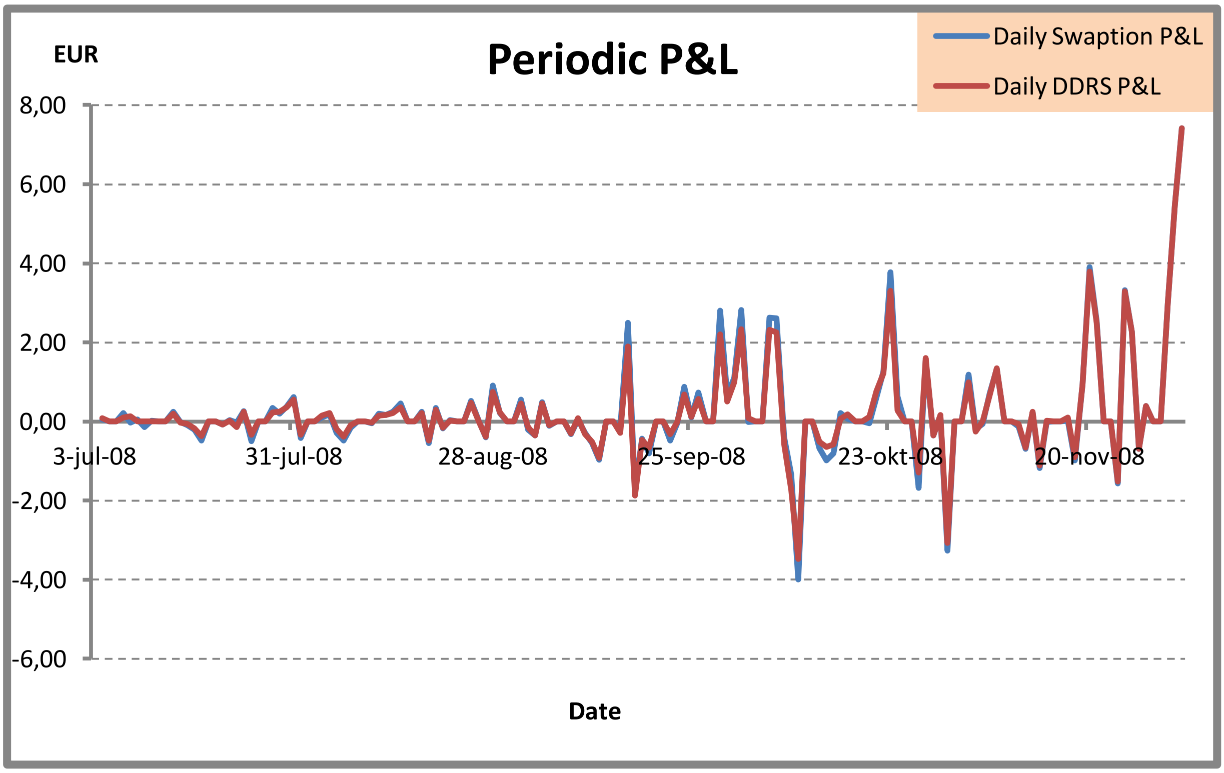

figure 31. **Development daily P&L -** In the figure, the P&L development of the swaption strategy and the DDRS has been plotted. As the simulation finished in the money, the swaption delta converged to -1. High delta at the end of the simulation caused the high volatility of the daily P&L's.

In *figure 31* the development of the periodical P&L's is shown. Again the swaption P&L is more volatile than the DDRS P&L. However this time the differences are small. The combination of decreasing interest rate with increasing IV caused the periodical P&L of the strategies to converge to each other. As the swaption expired ITM, total P&L was positive for both strategies and the total swaption return was higher than the total DDRS return.

4.4.2.1 Delta in market IV and fixed IV environment

As the DDRS performance is closely related to the delta development of the swaptions, the DDRS P&L might change if a constant IV is used instead of the market IV. A four months swaption from September 3rd, 2008 until January 5th, 2009 was simulated to present the delta development in both cases. As the swaption expires ITM, the delta converged to -1 at the expiration date. See *figure 32* for the development of the variables. The graph shows the development of the delta in case of market IV simulation and in case the IV during the simulation is kept constant at the IV level at inception. On the right y-axis the swap rate is given. On the left y-axis the delta (*100), the market IV (%) and the constant IV (%) is given.

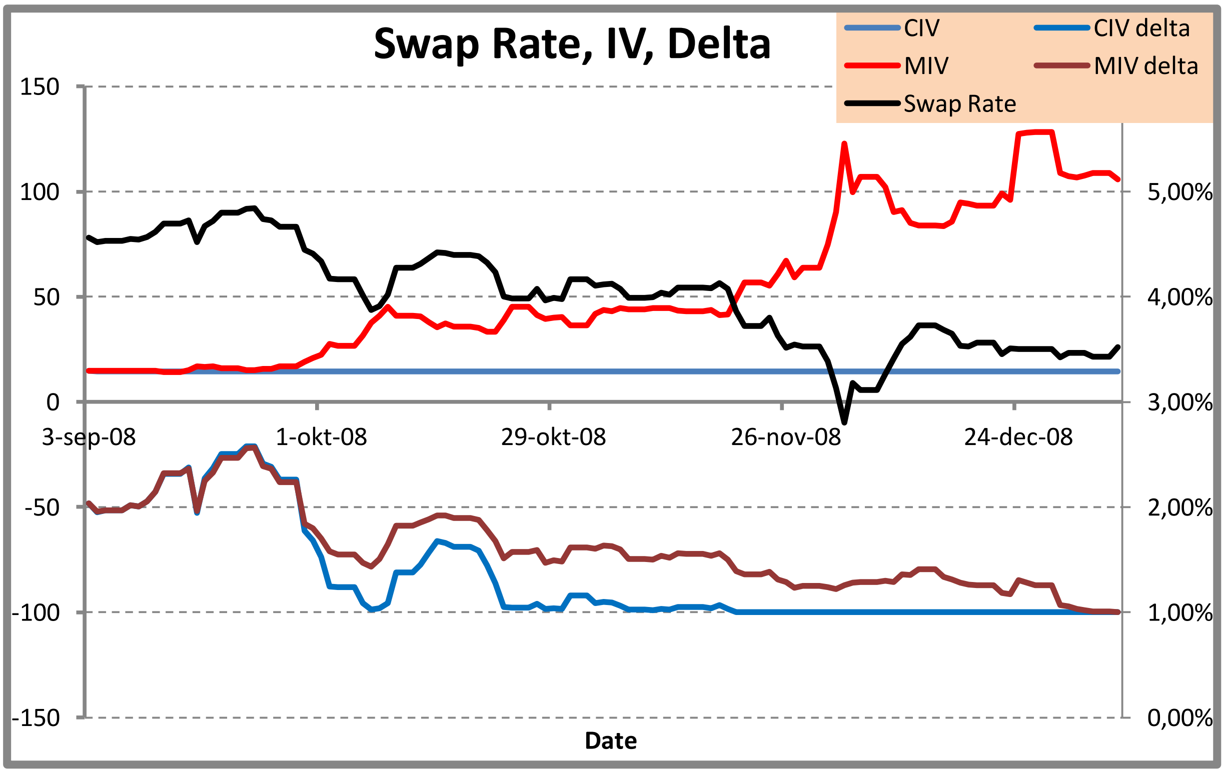

figure 32. **Delta development in market IV and constant IV environment -** In the figure the development of the swaption delta in market IV environment and constant IV environment is compared. The delta in constant IV environment reached -1 soon, while in the market IV environment the delta developed more steadily.

The delta in market IV environment developed relatively smooth compared to the delta in the fixed IV environment. In situations of dropping interest rate, the delta in market IV environment reacted less strong to changes of the underlying interest rate as in the constant IV environment. The development of the delta in the market IV environment showed an interesting pattern at for example December 3rd, 2008. The swap rate drops 33 bps at that date to 2.80%, the market IV increased to 123% from 90% one day before. The delta moved to -0.87 from -0.89 at the previous day. This is surprising, as decreasing interest rates made the swaption more ITM, the delta should converge to -1. However in this situation the delta moved away from -1.

The deltas changed less strong than expected. This is caused by the increasing IV, which in this case goes together with decreasing interest rates. The delta is affected by two opposing effects. The decrease of the swap rate caused the delta to converge to -1, however the increase of the IV has opposing effect and slowed down this development of the delta. This is made clear by the comparison of the delta development in a swaption simulation with market IV and constant IV, presented in *figure 32*. The net effect is that with strongly decreasing interest rates, the market value of swaptions does increase, but the delta does not. This means that at the bottom of the market, a DDRS based on the delta with market IV will always lag behind the value of the swaption.

The development of the market IV delta is less volatile. Due to this property, smaller delta trades are needed in the DDRS and the consequence is lower trading costs of the DDRS. In the mentioned simulation the swap trading cost in market IV is EUR 0.13, while in constant IV simulation the trading cost is EUR 0.14.

More important is the hedging error. As the trade cost change is small, any change of the relative efficiency of the DDRS is due to the hedging error. In this simulation the swaption strategy happened to be more efficient than the DDRS. In the market IV case the swaption performed EUR 4.22 better than the DDRS. In the constant IV case the swaption performed only EUR 2.26 better. The reason for this is that the swaption expired ITM. As the delta in constant IV simulation converged to -1 very rapidly, DDRS P&L followed almost perfectly the swaption P&L from that moment on. This was not the case in the market IV case. The delta reached -1 at the very end of the simulation. Until that moment the DDRS P&L followed the swaption P&L partly. This reason, among others, causes the big difference in the efficiency of the DDRS over the total life time of the simulation.

Hereby one remark has to be made. As the delta of a swaption changes slowly in decreasing interest rate market circumstances, the swap trader of the DDRS needs to trade a smaller swap notional in crash times. As the trading costs in crashing markets is high (high swap market bid-offer spread) and finding trading partner could be difficult, the discussed property of the delta development in the market IV simulations helps to solve this problem partly.

4.4.2.2 Market IV versus constant IV simulations

To get a general view of the relative efficiency of the DDRS with respect to the swaption strategy for different IV regimes, a couple of simulations has been performed with constant IV and compared with the market IV simulations.

As the DDRS performance is closely related to the delta development of the swaptions, the DDRS P&L might change if a constant IV is used instead of the market IV. In the previous paragraph is shown that the delta position of swaptions did not change as expected when the interest rate decreased very rapidly. In that case, one would expect the delta to converge to -1. However, my simulations showed that the delta stayed relatively constant. This was caused by the rapid increase of the IV due to the rapid change of the interest rate. While the swaption gained value by the interest rate drop and increased IV, the delta stayed constant. This prevented to buy more swaps in the DDRS. This pattern of the delta development might have substantial effect on the DDRS P&L. To test this expectation, I simulated the crisis period with a delta based on constant IV and compared this to simulations with a delta based on market IV from previous analysis. For this analysis, I used 6 to 30 months swaptions with maturity steps of 6 months between April 2006 and April 2011, in total 160 simulations with market IV and 160 simulations with constant volatility are compared with each other. The constant volatility is set at the initial IV. In *table 19* can be seen that the difference between the swaption strategy P&L and the DDRS P&L became more in favor of the swaptions when constant IV was used. This development is caused by the fact that in the DDRS, delta development becomes more volatile in the constant IV environment.

Maturity	Average PLD market IV	Average PLD constant IV
6	EUR -0.33	EUR -0.31
12	EUR 0.25	EUR 0.50
18	EUR 0.85	EUR 1.47
24	EUR 1.29	EUR 3.17
30	EUR 2.02	EUR 5.44

***table 19.* Average PLD for market IV and constant IV** - The simulation results are provided to compare the simulations in market IV environment and in constant IV environment. Only PLD's for 6, 12, 18, 24 and 30 months are given.

Due to the higher delta volatility more deltas (swaps) have to be traded in the constant IV simulations. Due to the "buy high, low sell" strategy of the DDRS, trading more deltas (swap notional) led to higher hedging error. Intuitively, with a delta that is higher in times of low interest rates, a higher swap notional is bought at the very bottom of the market: once interest rates rise again, this position leads to a greater loss and consequently leads to lower performance of the DDRS. In the simulations this led to higher gap between the swaption strategy performance and the DDRS performance. The PLD difference tend to increase for higher maturities much more compared to the shorter maturities. In the longer maturity simulations, the swap trades have to be executed more often. This caused the higher difference.

The constant IV simulation is interesting when the swaption or the DDRS is seen in perspective of the liabilities. The constant IV simulations have more appropriate delta position for the hedging purpose. If the hedge is regarded as independent from the liabilities, the stochastic IV DDRS provides better hedge.

4.4.3 Rapid decreasing interest rates

Rapid move of the underlying interest rates is an interesting scenario for this research. The financial crisis period included this scenario. Last three months before the December 2008 crash provides me this opportunity. In the period between September 3rd, 2008 and December 3rd, 2008 the 30 years interest rate moved down 175 basis points. The fastest move took place in the last month when the mentioned interest rate moved down 129 basis points.

Maturity	Swaption premium	Swaption P&L	DDRS P&L	PLD
1	EUR 3.11	EUR 21.54	EUR 21.28	EUR 0.26
2	EUR 2.82	EUR 23.18	EUR 21.29	EUR 1.89
3	EUR 2.17	EUR 31.30	EUR 28.29	EUR 3.01

***table 20.* Simulation statistics of rapidly decreasing interest rates** - The table provides figures which characterize the simulations in rapidly decreasing interest rate environment. The higher maturities show the relative gain of the swaption strategy.

The simulation of the one month swaption finishing at December 3rd, 2008 provided EUR 0.26 higher return compared to the DDRS. The simulation of the two month swaption provided EUR 1.89 and the three month swaption provided EUR 3.01 more than the DDRS. Surprisingly, the one month swaption P&L is close to the DDRS P&L. However the two months and the three months simulation shows a substantial difference. The given P&L differences for the two months and the three months simulations are really high when they are compared to the initial swaption prices. However the differences are relatively small when they are compared to the P&L of the swaptions. For the exact numbers, see *table 20*.

4.4.4 Rapid increasing interest rates

After the crash in December 2008, a rapid recovery took place in the interest rate markets. The 30 years interest rate moved up 62 bps in the first months, another 17 bps in the second months. In the third month, the interest rate decreased 14 bps. The recovery is low compared to the crash, but it is still high and can be used for this analysis. Due to increasing interest rates the receiver swaption strategies lost the premium. The DDRS has negative P&L as well. However the DDRS loss was smaller, such that 10% of the one month swaption, 25% of the two months swaption and 30% of the three months swaption premium could be saved by applying the DDRS. The key figures are shown in *table 21*. Compared to paragraph 4.4.3, the remark has to be made here, that the swaption premium are at substantial higher level due to the high IV. If the IV had been lower, the results might be totally different.

Maturity	Swaption premium	Swaption P&L	DDRS P&L	PLD
1	EUR 4.76	EUR -4.76	EUR -4.30	EUR -0.47
2	EUR 6.44	EUR -6.44	EUR -4.82	EUR -1.62
3	EUR 7.46	EUR -7.46	EUR -5.15	EUR -2.31

table 21. **Simulation statistics of rapidly increasing interest rates** - The table shows key figures of simulations for rapidly increasing interest rate environment. Especially the higher maturities show the relative gain of the DDRS.

5 Summary and conclusions

To research the relative efficiency of swaption delta replicating strategy with the swaption strategy, a model is used which provides insight into the performance of both strategies. The differences between these numbers are calculated to express the relative efficiency in one number, the PLD.

In the first step of this research swaptions and the DDRS with a base case scenario set has been simulated. The simulations showed several dependencies for the relative profitability.

1. The maturity of the swaptions matter for the relative profitability. On average, the short maturities are in favor of the delta replicating strategy, while the long maturities are in favor of the swaption strategy.
2. The swaption premium influences the profitability of the swaption strategy compared with the DDRS. The swaptions which are purchased at a relatively high price lose their attractiveness for investors. This is shown by adding simulations in which the relatively expensive long maturity swaptions are included.
3. Adding trading costs to the simulations resulted in a better performance of the swaption strategy. The trading costs for DDRS are on average higher than the trading costs of the swaption strategy. As the trading costs increase in stress times, the swaptions become relatively more efficient. One development in favor of the DDRS is that one needs to trade a smaller notional in crisis times than expected. The IV effect on the swaption deltas make it less volatile.
4. As the trading costs make the DDRS less attractive, the investor can choose to save costs by rebalancing the DDRS less frequently. The consequence of less number of trades is that the hedging error may increase. This is indeed the case for rebalancing period of one week. However for longer rebalancing periods, the average hedging error diminishes. In the most extreme case of no intermediate rebalancing, the DDRS return became as high as the swaption strategy. This does however also lead to greater uncertainty regarding the hedge result, especially when the initial swaptions expires ITM.
5. The scenario analysis shows that the DDRS tends to perform better than the swaption strategy in case of rising interest rates, while in case of decreasing interest rates, the reverse is true. Although the exact direction of interest rates is off course never known in advance, this information does indicate that the probability of a DDRS outperforming a swaption will increase when interest rate levels are relatively low.

The robustness of these conclusions have been tested by various sensitivity and robustness checks. Simulations at different start days showed that for the short maturities the start date doesn´t change the relative efficiency of the swaption strategy compared to the DDRS. However, for the longer maturities the swaptions became relatively more efficient for all other start days. This suggest that the PLD for longer maturities are underestimated due to the start day bias.

The main goal of this research is whether the swaption strategy or the DDRS is more appropriate for the liability hedging purposes. This question also depends on the method used to replicate, especially the way the delta is calculated. To see how this impacts results, constant IV simulations were performed. In these simulations the DDRS performance worsened. Due to the more volatile delta development in the constant IV environment, higher swap trades in the DDRS need to be performed. This causes the DDRS to incur more costs than before. Although the DDRS hedges the liabilities better according the constant IV delta development, this is worse for the DDRS average performance.

This thesis is a basic research in which liability hedging strategies are compared. As the time period, the means and the scope for this research are limited, more sophisticated research needs to be performed to draw firm conclusions. This research can be extended in several ways.

1. The first recommendation is the extension of the research for simulations in which the rebalancing of the swaps is based on a market value trigger instead of fixed time period basis. Lack of data prevented us to perform such a research.
2. Second recommendation is the extension of this research by simulating longer time periods. The time period in this research is only nine years, adding longer time period may provide new insights. This could be done either by looking for more reliable data before 2002, or by waiting until substantially more and new data is available in the future.
3. The research could further be completed by performing the analysis in a simulation model. This could substantially improve the risk analysis, as more insight could be given in the probability of outperformance and the underperformance of the DDRS.
4. The fourth extension could be the use of real trading costs. As reliable data on the market spread data was not available, this research could be redone using real market spread data once available.
5. As this research captures the European markets only, the fifth extension can be the investigation of swaptions in other currencies.
6. Sixth recommendation is the extension of the research for starting simulation at any day of the months. As the starting day is affecting the simulation results, more research is needed to explain this thoroughly.

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