The effect of target duration on the volatility of interest payments

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1. Introduction

Interest rate risk is a very common financial risk for corporates. Almost all firms have interest bearing debt or investments. In an Ernst & Young survey (Ernst & Young 2005) for large corporates 94% indicated that they are exposed to interest rate risk. More than half of the respondents included interest rate risk management among top three risk management functions in their organization.

Interest rate risk management with derivatives has increased rapidly since the introduction of interest rate swap market in 1982 (Titman 1992). In June 2009 the amount of outstanding over-the-counter (OTC) interest rate derivatives was 437 198 billion USD making it the largest OTC derivatives market (BIS 2009). Depending on the sample studied 30%-80% of respondents use interest rate derivatives. Use of derivatives varies between countries and industry sectors. A typical user is a large corporate in a developed country but use among smaller corporate is growing rapidly. (see e.g. Bartram et al. 2006, Bodnar et al. 1998, Hakkarainen et al. 1994)

An interest rate swap continues to be the most commonly used interest rate derivative (BIS 2009). An interest rate swap enables a firm to fix the interest payments on a floating-rate issue or to convert a fixed-rate bond to floating rate (Goodman 1990). The former – swapping from floating to fixed rate – is more commonly used. For example, in Bodnar et al. (1998), 96% of interest rate derivative users use derivatives in this fashion. Fixing interest rates using a swap improves forecastability of cash flows, provides a hedge from rapidly increasing interest payments and enables a firm to manage interest rate risk independently of loan maturity (see e.g. Flannery 1986, Titman 1992)

Firms with an advanced risk management function set risk limits to guide their interest rate risk management and derivatives usage. Commonly used risk limits are fixed-to-floating ratio, duration and average interest rate period (see e.g. Ernst & Young 2005, Hakkarainen et al. 1994). To list a few, UPM-Kymmene has target duration of 6 months, Neste Oil 12 months, YIT 24 months and Fortum 12-24 months (see 2009 Annual reports of the respective companies).
The objective of this paper is to quantify what is the actual effect of a particular target duration or average interest rate period on the volatility and forecastability of cash flows. We will study the interest payment cash flows while systematically maintaining a particular target duration with interest rate swaps. The target durations compared are the most commonly used levels of six, 12, 18 and 24 months.

Further, while several firms manage their interest rate risk, only few do benchmarking for this activity (see e.g. Bodnar et al. 1998 and Ernst & Young 2005). Thus, we aim to maintain the target duration using a hedging strategy that would also suit well for benchmarking purposes.

2. Interest rate risk in financial instruments

The introduction of the common currency EUR has decreased the volatility of interest rates somewhat. However, they still remain volatile as characterized, for example, by the fall in euribor rates from 5% to below 1% in less than 10 months in 2008-2009.

![Figure 1: Time series of EUR interest rates](image)

The volatility of interest rates depends on the maturity of the underlying rate. Figure 2 shows the implied volatility of one and five year interest rate starting in one and five years’ time. The shorter the underlying rate is the higher the volatility. Further, the shorter the time until the start
of the interest rate period is the higher the volatility. At the time of writing, interest rate volatility is at its highest level in recent years.

Figure 2: Time series of implied volatility of one and five year interest rates

Changes in interest rates affect directly the values and cash flows of financial instruments. An increase in interest rates decreases the market value of a fixed rate investment as it increases the discount rate. On the other hand, an increase in interest rates is also harmful for a firm that has floating rate debt as it increases the interest payments.

Figure 3: Effect of an increase in interest rates on fair value and cash flows

The shorter the maturity of the interest fixing of an interest bearing instrument is, the bigger the volatility of cash flows. Conversely, the longer the fixing is, the larger the volatility in market value. Therefore, a firm needs to decide what drives the management of interest rate risk – the
risk in cash flows or market values. An investor that invests in interest bearing instruments is likely to be interested in changes in the market value of the investments. On the other hand, one could argue that a firm with net debt should be more concerned about its cash flows than the market value of its debt as it is not going to repay the debt prematurely. This is supported also by the observation in Bodnar et al. (1998) that non-financial firms use interest rate derivatives mainly for fixing interest payments thus reducing cash flow risk but increasing fair value risk.

**Figure 4:** A short rate creates volatility in interest payments, a long rate in market value

The interest rate curve is typically upward sloping. Long term rates are often higher than short term rates. Figure 5 below shows the average shape of the EUR interest rate curve since 1999. For example, the five year rate has been on average 0.90 %-points higher than the three month rate.

**Figure 5:** EUR area interest rate curve, average, min and max levels
Further, Figure 6 compares the five year rate and the average of floating three month rate for the same five-year period. The five year rate has been lower only on a few occasions. The average of floating rate has been on average 1.30 %-points lower. This means that fixing interest rates comes at a cost. A firm needs thus to strike a balance between reducing risk and the cost of hedging. The target duration needs to be long enough to reduce cash flow risk to acceptable levels but not too long to introduce high hedging costs.

![5 year rate vs. floating rate for same period](image)

**Figure 6: 5 year fixed rate vs. floating rate for same period**

### 3. Measuring interest rate risk

**Fixed-to-floating ratio**

A simple way to measure and manage interest rate risk is to set a target on how much of the debt portfolio needs to have a fixed interest rate. Fixed-to-floating ratio is very easy to understand and to communicate to internal and external stakeholders. It has its limitations though. For example, it divides the interest fixings only to two classes. The boundary between fixed and floating is typically defined to be 12 months. A fixing that is longer than 12 months is considered fixed, all other floating. Thus, this measure makes a clear distinction between a fixing that is 11 months and a fixing of 13 months. It, however, makes no distinction between a fixing of 13 months and 13 years while the hedge these two fixings provide is hugely different.
The fixed-to-floating ratio can, thus, also be very volatile. If a firm has a fixing of 13 months on all its debt the fixed-to-floating ratio falls from 100% to 0% in one month. Therefore, while it is a useful measure, the fixed-to-floating ratio should not be used as the only measure of interest rate risk.

**Duration**

Faulhaber and Baumol (1988) note that the concept of duration is among a few major innovations devised by economists in the last few decades that has had a major impact on how firms cope with market forces. Duration has its origins in the work of Macauley (1938) and Fisher and Weil (1971) showed how it could be used to minimize the interest rate risk in the construction of a bond portfolio.

Duration can be written as

\[ D = \sum_{t=1}^{N} w_t t \]  

(1)

where

\[ \sum_{t=1}^{N} w_t = 1, \quad 0 \leq w_t \leq 1 \]

Here \( w_t \) is a weight that applies to date \( t \) for a security having \( N \) dated cash flows. For a security that makes one payment in each of the next \( N \) periods, the weights in the expression become

\[ w_t = C_t (1 + r)^{-t} / p, \quad t = 1, 2, 3, \ldots, N \]  

(2)

where

- \( C_t \) is cash flow in period \( t \)
- \( r \) is annual discount rate
- \( p \) is security price

Thus Equation 1 can be written as

\[ D = \frac{\sum_{t=1}^{N} C_t t}{\sum_{t=1}^{N} C_t (1 + r)^t} \]

(3)
An important property of duration is additivity: the duration of a portfolio can be calculated as a weighted average of the durations of individual assets.

\[ D_p = \sum_{i=1}^{n} \frac{p_i D_i}{P} \]  

(4)

where

\( D_P \) is portfolio duration
\( p_i \) is price of security \( i \)
\( D_i \) is duration of security \( i \)
\( P \) is price of portfolio

Thus, compared to fixed-to-floating ratio, duration takes into account the exact lengths of the interest fixings. The longer the duration of the portfolio is the larger the market value risk is but the smaller the cash flow risk is.

**Average interest rate fixing period**

The duration of a security depends on the level of its fixed coupon rate (see Equation 3). The higher the coupon is, the shorter the duration is. The level of interest rate fixing does not however, affect the forecastability or volatility of cash flows in any way. On the other hand, it would be valuable for a firm to know the average time until repricing of loan interest rates. For a zero-coupon bond the duration equals the length of the interest rate fixing – otherwise it is shorter.

Thus, for measuring the cash flow risk in a loan portfolio the concept of average interest rate fixing period may be more useful. For a single security the interest fixing period is the time until repricing of its interest rate. For example, for a five-year fixed rate loan it is five years when the loan is raised. One year later it has fallen to four years. In a floating rate loan where the firm pays six month euribor rate the fixing period is six months on the interest fixing date and, for example, three months in the middle of the interest fixing period. For a portfolio the average interest rate fixing period can be written as

\[ F_p = \sum_{i=1}^{n} \frac{a_i F_i}{A} \]  

(5)

where
Cash flow at risk

Cash flow at risk (CFaR) is the maximum shortfall of net cash generated, relative to a specified target, corresponding to some pre-defined probability level and risk horizon (RiskMetrics 1999). The probability level used – as defined by the left-hand tail of the cash flow distribution - is usually 5% or less. Figure 7 below depicts CFaR at the 5% probability level.

As a measure of interest rate risk, CFaR can be used, for example, to quantify how much higher the interest payments of a certain future period can be, at a certain probability, than those predicted by the interest rate curve. Figure 8 depicts the interest payments of a EUR 100 million floating rate loan as predicted by the forward rates and at 95% probability calculated using implied volatilities at the time of writing.
4. Hedging instruments

As discussed in Section 1 the most commonly used interest rate derivative is the interest rate swap. To hedge from interest rate risk in cash flows it can be used to fix the interest payments. In an interest rate swap the firm would thus agree to pay a stream of fixed cash flows in exchange for a stream of cash flows that depend on a floating rate. For example, a firm that has a loan in three month euribor may enter into swap where it pays a fixed rate and receives three month euribor. The euribor payment received under the swap agreement can be used to pay the euribor interest on the loan effectively fixing the loan interest. Figure 9 below shows the cash flows.

Thus, entering into a pay-fixed-receive-floating interest rate swap effectively lengthens the duration or interest fixing period of a loan portfolio. For example, swapping a floating three month euribor rate into a five year fixed rate increases the fixing period of the loan from three months to five years. If the nominal of the swap was only 50% of the nominal of the loan, the resulting average interest fixing period would be, using Equation 5:

\[
F_p = \frac{50\% \times 3\,\text{months} + 50\% \times 60\,\text{months}}{100\%} = 31,5\,\text{months} = 2,625\,\text{years}
\]

There are several other interest rate derivatives such as forward rate agreements, interest rate futures, vanilla options and exotic options that can be used as hedging instruments (see e.g. Hull 1997). These are, however, beyond the scope of this study.
5. Hedging strategy

Maintaining a certain fixing period is possible in several different ways. For example, one could systematically enter into forward rate agreements. However, as forward rate agreements are used by very few firms (see e.g. Bodnar et al. 1998, Ernst & Young 2005) and as they are not available for any period they are not optimal for benchmarking purposes. Therefore, we suggest that the benchmark is built using interest rate swaps which are by far the most commonly used interest rate derivative and which are available for any period.

A certain fixing period can also be achieved in many different ways using interest rate swaps. For example, one could enter into an interest rate swap the maturity of which equals the desired fixing period. After some time the swap would be closed and replaced with a new one to maintain the fixing period. This approach would, however, require frequent buying and selling of swaps leading to high transaction costs. Further, this practice would provide very little forecastability over future rates as the fixed rate would be constantly replaced by a new, different, fixed rate.

Thus, we suggest that the fixing period is maintained by having constantly a serially amortising set of swaps. This requires no selling of swaps. A swap is only replaced as it matures. As each swap is kept until maturity the forecastability of future rates is high. Further, this approach seems to approximate rather well the actual hedging practices of firms (see e.g. the 2009 Annual Reports of Fortum, Neste Oil, UPM-Kymmene and YIT).

To keep the average interest fixing period close to a target level of M months we are using interest rate swaps with a maturity of 2*M months. A new interest rate swap is entered every three months\(^1\). The swap entered effectively replaces an old hedge that matures in the same period. Thus, for example, the loan portfolio with a target fixing period of 12 months includes always eight swaps –maturing in three month intervals. On interest fixing day the maturities of

\(^1\) The rolling frequency could also be, for example, one month.
these swaps are three, six, nine, 12, 15, 18, 21 and 24 months. Three months later as their maturities are zero, three, six, nine, 12, 15, 18 and 21 months the maturing swap is replaced with a 24 month swap.

The procedure is reflected in Figure 10.

![Figure 10: Static hedging procedure for 12 month fixing period](image)

The resulting interest fixing period of the loan portfolio is at its shortest

\[
\frac{1}{8}(0 + 3 + 6 + 9 + 12 + 15 + 18 + 21) = 10.5 \text{months}
\]

and at its longest

\[
\frac{1}{8}(3 + 6 + 9 + 12 + 15 + 18 + 21 + 24) = 13.5 \text{months}
\]

On average the fixing period is 12 months.

Similarly, for other target levels of average fixing period the amount of interest rate swaps in the portfolio is \( F_{PF} \times \frac{2}{3} \), where FPT is the targeted fixing period in months. Further, the nominal of each interest rate swap is \( 100\%/(F_{PF} \times \frac{2}{3}) \).

The hedging strategies compared include a targeted fixing period of six, 12, 18 and 24 months.
6. Results

The data used in calculations includes monthly fixings for the following EUR area interest rates:
- 6 month euribor
- 1, 2, 3 and 4 year swap rate

Further, CFaR calculations are conducted using a time series of EUR area swaption volatilities. The analysis is conducted on monthly data from 1999-2010. Data source is Reuters.

Figure 11 below shows the development of the average interest rate of the portfolio with the six month and the 12 month fixing period. As can be noted, lengthening the fixing period from six to 12 months decreases the volatility of interest payments. Changes in average interest rate are less pronounced and the highest peaks as well as the lowest dips are smoothened.

Figure 11: Average interest rate with six and 12 month fixing periods

Further lengthening the fixing period reinforces the smoothening effect. Figure 12 shows the interest rate development with 18 and 24 month fixing periods.
Figure 12: Average interest rate with six, 18 and 24 month fixing periods

Figure 13 shows the 95% CFaR for the chosen fixing periods. CFaR is calculated at each point for the sum of interest payments in the following four year period\(^2\). It is shown as the difference between interest payments according to the forward curve versus interest payments at 95% probability. While the hedging strategies have been static during the whole period, the volatility of interest rates has changed causing changes in CFaR figures. The CFaR has on average been 7% for the six month fixing period and 4% for the 24 month fixing period. The maximum levels have been 12% and 7%, respectively. This means that a longer fixing period increased markedly the forecastability of future interest payments. Lengthening the fixing period from six to 24 months decreases the 95% CFaR of four year interest payments by more than 40%.

\(\text{CFaR 95\%, four year interest payments}\)

\(^2\) Four years is chosen as it is the length of the longest swaps used in the analysis.
Table 1 summarizes the calculation results. Lengthening the fixing period decreases the risk in interest payments in several ways. The maximum level of interest payments remains lower. The volatility of average interest rate is four times smaller for 24 month fixing period than it is for six months. Further, the biggest 12 month change in average interest rate has been almost seven times smaller.

The decrease in CFaR is also large. On a two year horizon the CFaR of 24 month fixing period is very small because the hedging ratio is very high – on average 75% - for these years. The decrease on a four year horizon is, however, also very good as discussed above. For the fifth year the CFaR would be similar for all strategies as the hedging ratio is 0% for that year also in the 24 month strategy.

In all measures, the risk falls remarkably already by lengthening the fixing period from six to 12 months. Thereafter the risk continues to fall but at a slightly slower pace.

The fall in risk provided by a longer fixing period does not come without a cost, however. The average interest rate has increased with the fixing period. For the 24 month fixing period the average interest rate has been 0,65 %-points or 20% higher than for the six month fixing period. Therefore, there is a tradeoff between the benefits and costs of interest rate risk management.

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<th>6 months</th>
<th>12 months</th>
<th>18 months</th>
<th>24 months</th>
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<td>Max (%)</td>
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<td>4.80</td>
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<td>Volatility, 3m (bp)</td>
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<td>20</td>
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<td>9</td>
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<td>Biggest 12m change (bp)</td>
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<td>104</td>
<td>75</td>
<td>59</td>
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<td>CFaR 95%, 2 years, (avg)</td>
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<td>1.4%</td>
<td>0.9%</td>
<td>0.7%</td>
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<td>CFaR 95%, 2 years, (max)</td>
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<td>CFaR 95%, 4 years, (avg)</td>
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<td>CFaR 95%, 4 years, (max)</td>
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<tr>
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<td>Cost of hedging (bp)</td>
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Table 1: Effect of fixing period on interest payments
7. Conclusion

Successful risk management requires risk limits. For interest rate risk at corporates, these limits can be set by using target duration or interest fixing period. In this paper, we quantify the effects of choosing a particular target duration or fixing period on the interest payment cash flows.

The risk as measured by several different measures falls by lengthening the fixing period from six to 12, 18 or 24 months. For example, a firm that has a EUR 100 million loan portfolio and a 24 month fixing period will know that at 95% probability the interest payments of the coming two years will not exceed those suggested by the forward curve by more than EUR 0,7 million. If the fixing period was only six months, the firm would need to be prepared for an additional cost of EUR 2,3 million.

On the other hand, lengthening the interest fixing period increases the average interest rate. For a 24 month fixing period this increase in average interest rate has been 0,65 %-points – EUR 0,65 million per year for a EUR 100 million loan portfolio. Thus, there is a tradeoff and each firm needs to decide what is the level of protection they need and how much they are willing to pay for it. The results of this study will help firms to justify their decisions.

Successful risk management requires also benchmarking. Benchmarking has not been common in financial risk management at corporates. The hedging strategies constructed in this paper are suggested as benchmarks for six, 12, 18 and 24 month fixing periods. They should serve well as benchmarks as they resemble closely strategies that firms actually use. Further, they are executable – they require only one transaction per three months. Finally, data needed for calculating these benchmarks is easily and readily available.
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