[Title]

Bachelor's Thesis

Submitted in partial fulfillment of the requirements for the degree of Bachelor of Arts in Economics and Business Administration

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Task Assignment

Executive Summary

Contents

List of Figures

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Chapter 1

[Chapter Title]

1.1 [Section Title]

[...] Between sections and subsections, you may want to add at least three or four sentences (or more), instead of leaving it blank.

1.1.1 [Subsection Title]

The same principle obviously holds for subsequent levels.

1.2 LaTeX Basics

[...] In the next subsections, there is the basic information you will need to know and/or is useful to get started with your thesis in LaTeX. All the packages that are mentioned are already included in the 'preamble.tex' file, so you are all set to go to use the presented commands. First, make sure to choose the correct setting on top of this tex file w.r.g. to your program and level (bachelor/master). These settings will automatically lead to the correct title page for your Bachelor thesis. Next, adapt all the necessary parts (e.g. Author, title, running title, Bachelor/Master, ...) in the preamble file.

1.2.1 Useful sources

- TeX distribution: MiKTeX
- Editor: VSCode, TeXMaker, OverLeaf (online)
- Other resources wikibooks, stackexchange and other

1.2.2 Plain text

You can write simple text in **bold**, *Italic*, underlined or *emphasized*. In different font sizes from tiny to Huge. Also in different colors red text, green text, own defined color . . . . Obviously, you can also mix things up ***test***

Be careful with special characters like %, }, {, & and \. Indentation is 'fixed' with the package *setspace*.[1]. Do not use the simple quotation marks "quote", instead use "quote".

1.2.3 Lists

There are different types of so-called list environments: Unordered, Ordered and Description. They can be nested, up to a depth of 4:

Description This type of list (description)

Unordered Simple bullet points (itemize)

- Item 1
- Item 2
- . . .

Ordered List with order in bullet points (enumerate)

1. Item 1
2. Item 2
3. . . .

[1] Also for footnotes, thanks to *footmisc*

1.2.4 Math and Equations

You have in-line math environments, for example good for the use of a subscript α_1 or a superscript α^2 (or both at the same time α_{sub}^{super}), but also dedicated and centred environments. The most basic one is:

$$x_i$$

The 'equation' environment

$$\mathbb{E}_t^{\mathbb{Q}}\left[\frac{X_{t+1}}{B_{t+1}}\right] \tag{1.1}$$

The 'align' environment

Perfect for having multiple equations in one environment so they can be aligned using the & symbol.

$$R_{i,t} = \alpha_i + \beta_i R_t^{mkt} \tag{1.2}$$

$$R_{i,t} = \alpha_i + \beta_i R_t^{mkt} + \gamma SMB_t + \theta HML_t \tag{1.3}$$

If you do not want equation numbers you can either use '\nonumber' within the environment or use * in environment name.

$$\begin{aligned} R_{i,t} &= \alpha_i + \beta_i R_t^{mkt} \\ R_{i,t} &= \alpha_i + \beta_i R_t^{mkt} + \gamma SMB_t + \theta HML_t \qquad (1.4) \end{aligned}$$

$$\begin{aligned} R_{i,t} &= \alpha_i + \beta_i R_t^{mkt} \\ R_{i,t} &= \alpha_i + \beta_i R_t^{mkt} + \gamma SMB_t + \theta HML_t \qquad \forall i \end{aligned}$$

The proof in Appendix A.1 provides even another example of a math environment.

1.2.5 Floats

Float environments have everything to do with tables and figures.

Tables

The actual table content is wrapped in a *tabular* environment, while making a proper table from it, including caption, description, . . . is done by the *table* environment.

Table 1.1 – Table title

This is a description

Column 1	**Column 2**	**Column 3**
left	center	right
left	center	right
1	2.547	1000.5

Figures

Figures are wrapped in the *figure* environment. To keep things organised, you can put all your graphics into a dedicated folder and input them via the *includegraphics* command within the *figure* environment.

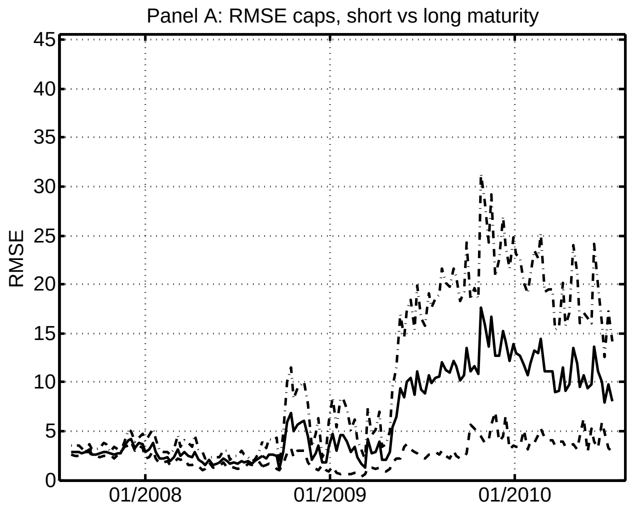
The following subsection presents an example where tables and figures are imported from separate tex files via the *input* command and are referenced to in the text using their labels.

1.2.6 Pricing Errors

[. . .] we present the root mean squared pricing errors (RMSEs) and the mean pricing errors (MPEs) on caps and swaptions implied volatilities, defined as the difference in percentage points between the model-implied values and the market-implied volatility quotes. Overall, we find that, for intermediate

Figure 1.1 – This is a figure

description again



and long maturities, our model performs remarkably well. The cap pricing errors in Table 1.2 indicate that the model's performance suffers mostly at the short end of option maturities, especially for the one-year maturity. Short maturity contracts are underpriced by the model. However, the pricing performance considerably improves with increasing maturity. For longer maturities, a tendency exists to underprice out-of-the money and overprice in-the-money contracts.

Table 1.2 – Pricing errors for the caps market.

Reported are sample averages of the root mean squared errors (RMSEs) and mean pricing errors (MPEs) for caps implied volatilities, defined as the difference in percentage points between the model-implied values and the market-implied volatility quotes. Each row represents one cap maturity, and columns represent the moneyness of the cap.

	RMSE					MPE				
Maturity	0.80	0.90	1.00	1.10	1.20	0.80	0.90	1.00	1.10	1.20
One year	16.86	18.62	20.15	20.30	22.03	-10.73	-11.08	-11.95	-12.32	-15.96
Two years	12.26	11.71	9.79	9.57	9.85	-8.64	-8.77	-6.99	-6.17	-7.01
Three years	8.78	6.75	4.75	4.19	4.02	-6.67	-5.15	-3.44	-2.52	-2.59
Four years	6.47	4.29	2.25	1.66	2.03	-4.81	-2.98	-1.40	-0.48	-0.06
Five years	4.98	2.94	1.35	1.26	2.18	-3.41	-1.67	-0.30	0.56	1.29
Six years	4.28	2.36	1.41	1.68	2.50	-2.63	-0.92	0.31	1.11	1.97
Seven years	3.91	2.16	1.71	2.08	2.71	-2.07	-0.38	0.74	1.48	2.25
Eight years	3.63	2.07	1.89	2.27	2.80	-1.71	-0.07	0.95	1.63	2.33
Nine years	3.48	2.09	2.04	2.42	2.88	-1.35	0.20	1.15	1.79	2.41
Ten years	3.37	2.15	2.18	2.54	2.95	-1.06	0.42	1.31	1.91	2.47

For the ATM swaptions implied volatilities in Table 1.3, we observe a similar pattern. The model struggles mostly for short option maturities and short swaption tenors, an observation that also holds true for the non-ATM swaptions. However, across moneyness no clear pattern emerges in terms of over- and underpricing as is the case for in-the-money and out-of-the-money caps.

The substantially higher pricing errors for the caps and swaptions market at shorter maturities call for further investigation. Ultimately, the caps and swaptions markets must be closely connected, as they both originate from derivatives written on the forward LIBOR. However, during periods of extreme market turmoil, the two markets might exhibit different behaviors due to differences in how the uncertainty regarding the intensified liquidity situation in the interbank market propagates through the caps and swaptions markets. Therefore, we next analyze the behavior of the pricing errors across time to see whether the caps and swaptions market become disintegrated or whether

Table 1.3 – Pricing errors for at-the-money (ATM) swaptions.

Reported are sample averages of the root mean squared errors (RMSEs) and mean pricing errors (MPEs) for ATM swaptions implied volatilities, defined as the difference in percentage points between the model-implied values and the market-implied volatility quotes. Each row represents one swaption maturity, and each column represents one swap tenor.

	RMSE							MPE						
	Swap tenor							Swap tenor						
Option maturity	One year	Two years	Three years	Four years	Five years	Seven years	Ten years	One year	Two years	Three years	Four years	Five years	Seven years	Ten years
Three months	21.16	9.66	4.46	4.82	5.94	8.30	10.32	-14.13	-7.24	-1.97	0.72	1.77	5.09	7.38
Six months	19.53	7.93	2.58	2.60	3.78	6.17	7.89	-13.67	-6.05	-1.45	0.90	1.93	4.35	6.10
One year	12.72	5.27	1.74	1.52	2.27	3.82	4.95	-8.81	-3.21	-0.43	0.86	1.48	2.83	3.84
Two years	4.20	2.20	1.49	1.31	1.36	1.61	2.04	-1.03	0.15	0.61	0.71	0.65	0.75	1.13
Three years	2.34	1.75	1.38	1.18	1.13	1.22	1.41	1.33	1.16	0.86	0.51	0.16	-0.05	-0.03
Four years	2.36	1.65	1.29	1.08	1.19	1.25	1.40	1.85	1.20	0.71	0.14	-0.17	-0.53	-0.65
Five years	2.36	1.65	1.35	1.25	1.32	1.51	1.67	1.89	1.13	0.49	-0.07	-0.47	-0.73	-0.88
Seven years	2.10	1.53	1.36	1.32	1.32	1.54	1.80	1.44	0.73	0.28	-0.16	-0.44	-0.74	-1.07
Ten years	1.93	1.56	1.40	1.39	1.42	1.53	1.72	1.32	0.88	0.50	0.22	-0.01	-0.47	-0.76

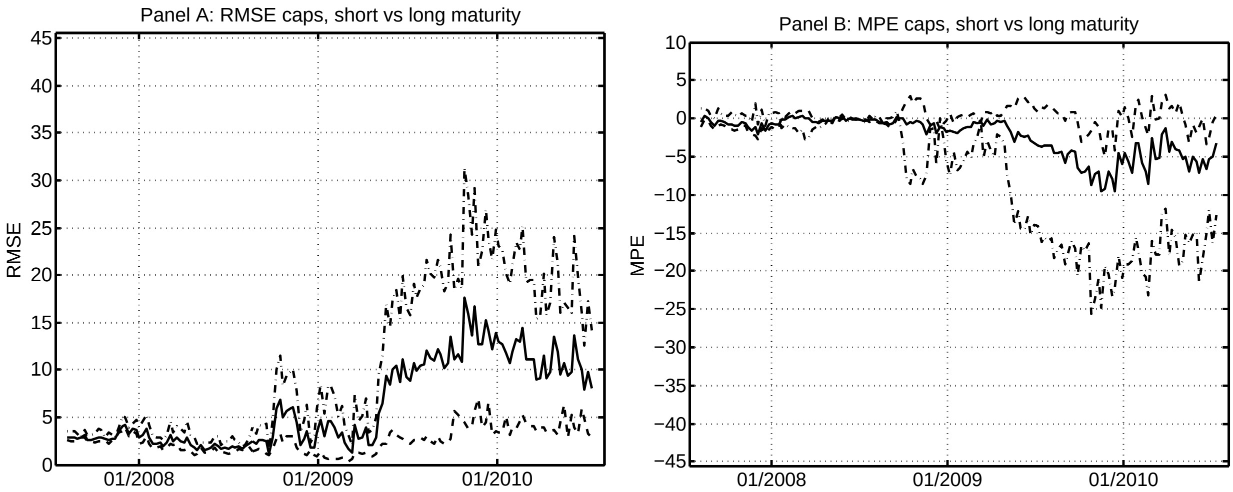


Figure 1.2 – Root mean squared error (RMSE) and mean pricing error MPE for caps with different option maturities. Panels A and B show the RMSE and the MPE in percentage points across time for caps implied volatilities of all maturities (solid line), for maturities up to three years (dash-dotted line), and for maturities of four to ten years (dashed line). Data are weekly (Wednesday) spanning our entire data sample August 8, 2007 to August 11, 2010; in total, 158 weeks.

they suffer from the same deficiencies.

In Fig. 1.2, we plot the time series of RMSE (Panel A) and the MPE (Panel B) for caps implied volatilities. We split the time series into long maturities and short maturities. For the first period of our data sample with the financial crisis already in full swing, the pricing errors in terms of RMSE remain remarkably low. In addition, until October 2008, we do not observe a bias in the model's pricing performance with the MPE close to zero. However, the pricing performance deteriorates considerably around April 2009 with substantial underpricing of short maturity contracts. This mispricing remains high until the end of our sample. Interestingly, this period of persistent mispricing of short maturity contracts coincides with the period of high implied volatilities at these maturities. Hence, our model suffers when the volatility term structure is unusually steep.

1.2.7 Other environments

listings

The package *listings* is used to present code in your document. But it seems there is a better alternative for python specific color highlighting.

```
input numpy as np

def square_root(x):
    return x**(1/2)

x=4
assert np.sqrt(x) == square_root(x)
```

or Matlab code

```
figure(1)
set(gca,'Box', 'on', 'LineWidth',1.5 ,'FontSize',14)
plot(x,cumprod(1+R(:,2)),x,cumprod(1+R(:,3)),'--',x,cumprod(1+R(:,4)),'-.','LineWidth',1.5)
grid on
datetick('x','mmmyy')
axis([x(1)-10 x(end) 0.5 3.0])
title('Panel A: Equity and commodity indices')
ylabel('Cumulative return')
grid on
legend('MSCI World Total Return', 'MSCI Emerging Market Total Return','DJ UBS Commodity Index')
print('-depsc2', 'cumReturnA.eps' )
```

1.2.8 A Note on Referencing

Bibliography

There are basically two options to include citations and references to your document: Bibtex or BibLatex. This doc is constructed using the latter, because it's newer and more flexible (e.g. allows use in *beamer* documentclass). There are different citing commands, each with a slightly different outcome: Bates 1996, Carr and Wu (2004) and (Heston 1993; Bates 1996). You can also combine citations, Petkova (2006) and Carr and Wu (2004). *textcite* is the one most commonly used, though *parencite* is useful too.

Other

There is also the option to refer to many other things (floats, footnotes, (sub)sections,. . .). With the *cleverref* package, you can easily refer to these object by using the 'cref' command. Eq. (1.2), Fig. 1.1, Footnote 1, Section 1.2.8, Table 1.1. You can also combine references of the same type of objects, just like citations, Eqs. (1.2) and (1.3).

[Here are some examples of citations. . .] Lévy processes cannot capture stochastic volatility, stochastic risk reversal (skewness) and stochastic correlation. These drawbacks can be resolved, at least to some extent, by considering time-changed Lévy processes for which it is possible to generate distributions which vary over time. If the return innovation is modeled by a Brownian motion, we can let the instantaneous variance be stochastic (see, e.g., Heston (1993) and Bates (1996)) to create dependence of the return increments.[2]

[2] Carr and Wu (2004), for instance, introduced a time-changed Lévy model to capture the leverage effect.

Chapter 2

[Chapter Title]

2.1 [Section Title]

2.1.1 [Subsection Title]

Appendices

Appendix A

Proofs

[You may also want to add an appendix, if it makes sense. You delegate proofs to the appendix or other material that is essential for the understanding of your work, but would distract the reader if placed in the main text. . .]

A.1 Proof of Proposition [. . .]

[. . . .], we can apply Ito's formula for Lévy processes to obtain the dynamics of the forward LIBOR $L(t, T_j)$ to obtain the dynamics of the forward LIBOR $L(t, T_j)$ under the T_{j+1}-forward measure as follows:

$$\begin{aligned} \frac{dL(t,T_j)}{L(t,T_j)} &= b(t,T_j,T_{j+1})dt + \frac{1}{2}\lambda^2(t,T_j)dt + \frac{1}{2}V_t^W dt \\ &+ \int_{-\infty}^{0} [e^x - 1 - x]\, \pi_{J^-}^{\mathbb{Q}_{j+1}}(dx)\nu_t^J dt + \int_{0}^{\infty} [e^x - 1 - x]\, \pi_{J^+}^{\mathbb{Q}_{j+1}}(dx)\nu_t^J dt \\ &+ \lambda(t,T_j)dB_t^{Q_{j+1}} + \sqrt{V_t^W} dW_t^{Q_{j+1}} + \int_{-\infty}^{0} [e^x - 1] \left[\mu^-(dt,dx) - \pi_{J^-}^{Q_{j+1}}(x)dx\nu_t^J dt\right] \\ &+ \int_{0}^{\infty} [e^x - 1] \left[\mu^+(dt,dx) - \pi_{J^+}^{Q_{j+1}}(x)dx\nu_t^J dt\right]. \end{aligned} \tag{A.1}$$

To ensure that $L(t, T_j)$ is a martingale under the T_{j+1}-forward measure, the drift must equal zero, which gives the drift condition in the proposition. ■

Bibliography

Bates, D S (1996). "Jumps and stochastic volatility: Exchange rate processes implicit in Deutsche Mark options". In: *Review of Financial Studies* 9.1, pp. 69–107.

Carr, Peter and Liuren Wu (2004). "Time-changed Lévy processes and option pricing". In: *Journal of Financial Economics* 71.1, pp. 113–141.

Heston, Steven L (1993). "A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options". In: *Review of Financial Studies* 6.2, pp. 327–343.

Petkova, Ralitsa (2006). "Do the Fama–French factors proxy for innovations in predictive variables?" In: *The Journal of Finance* 61.2, pp. 581–612.

Eidesstattliche Erklärung

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