

Thesis title

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Statistics, the University of Auckland, 2022. This thesis is for examination purposes only and is confidential to the examination process.

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Abstract

The abstract should outline the main approach and findings of the thesis and must not be more than 500 words.

Acknowledgements

I would like to thank my pet goldfish for ...

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Chapter 1

Introduction

This is where you introduce the main ideas of your thesis, and an overview of the context and background.

In a PhD, Chapter 2 would normally contain a literature review. Typically, Chapters 3–5 would contain your own contributions. Think of each of these as potential papers to be submitted to journals. Finally, Chapter 6 provides some concluding remarks, discussion, ideas for future research, and so on. Appendixes can contain additional material that don't fit into any chapters, but that you want to put on record. For example, additional tables, output, etc.

1.1 Rmarkdown

In this template, the rest of the chapter shows how to use Rmarkdown. The big advantage of using Rmarkdown is that it allows you to include your R code directly into your thesis, to ensure there are no errors in copying and pasting, and that everything is reproducible. It also helps you stay better organized.

For details on using *R Markdown* see <http://rmarkdown.rstudio.com>.

1.2 Data

Included in this template is a file called `sales.csv`. This contains quarterly data on Sales and Advertising budget for a small company over the period 1981–2005. It also contains the GDP (gross domestic product) over the same period. All series have been adjusted for inflation. We can load in this data set using the following command:

```
sales <- ts(read.csv("data/sales.csv"), [-1], start=1981, frequency=4)
```

Any data you use in your thesis can go into the data directory. The data should be in exactly the format you obtained it. Do no editing or manipulation of the data outside of R. Any data munging should be scripted in R and form part of your thesis files (possibly hidden in the output).

1.3 Figures

Figure 1.1 shows time plots of the data we just loaded. Notice how figure captions and references work. Chunk names can be used as figure labels with `fig:` prefixed. Never manually type figure numbers, as they can change when you add or delete figures. This way, the figure numbering is always correct.

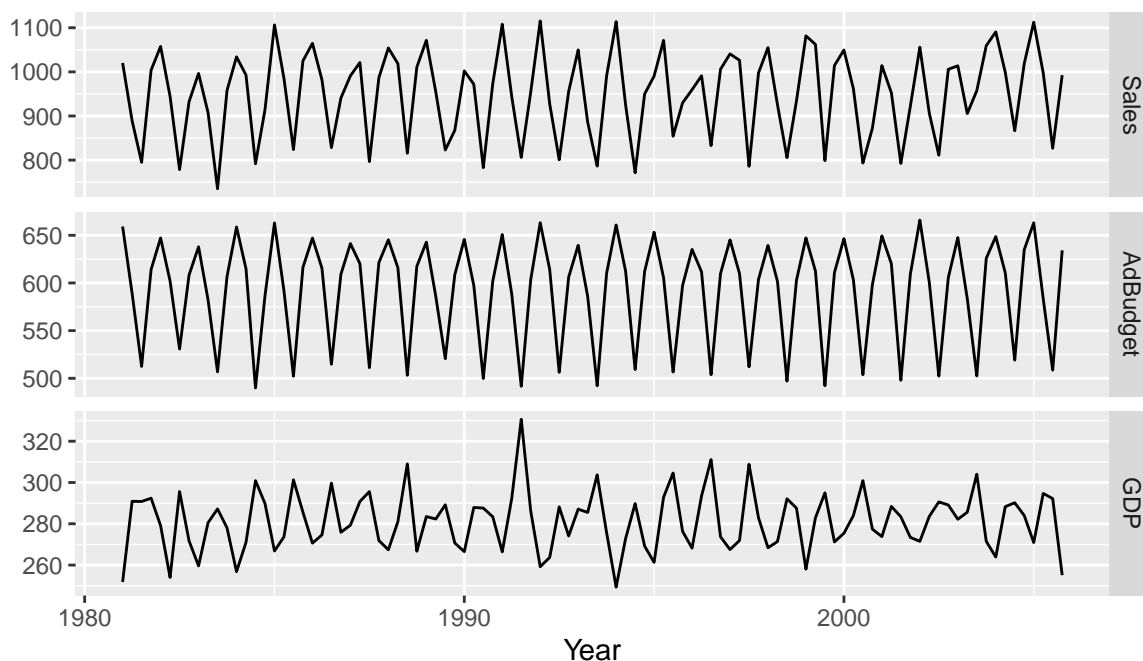


Figure 1.1: *Quarterly sales, advertising and GDP data.*

1.4 Results from analyses

We can fit a dynamic regression model to the sales data.

If y_t denotes the sales in quarter t , x_t denotes the corresponding advertising budget and z_t denotes the GDP, then the resulting model is:

$$y_t - y_{t-4} = \beta(x_t - x_{t-4}) + \gamma(z_t - z_{t-4}) + \theta_1 \varepsilon_{t-1} + \Theta_1 \varepsilon_{t-4} + \varepsilon_t \quad (1.1)$$

where $\beta = 2.28$, $\gamma = 0.97$, $\theta_1 = NA$, and $\Theta_1 = -0.90$.

1.5 Tables

Let's assume future advertising spend and GDP are at the current levels. Then forecasts for the next year are given in Table 1.1.

```
## Warning in sprintf(str, x, ...): one argument not used by format '\toprule
## Point Forecast & Lo 80 & Hi 80 & Lo 95 & Hi 95 \\
## \midrule'
```

```
## Warning in sprintf(str, x, ...): one argument not used by format '\toprule
## Point Forecast & Lo 80 & Hi 80 & Lo 95 & Hi 95 \\
## \midrule'
```

Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
1000.2	947.7	1052.7	919.9	1080.5
1013.1	959.3	1066.8	930.9	1095.3
1076.7	1022.9	1130.6	994.4	1159.0
1003.5	949.7	1057.4	921.2	1085.8

Table 1.1: *Forecasts for the next year assuming Advertising budget and GDP are unchanged.*

Again, notice the use of labels and references to automatically generate Table numbers. In this case, we need to generate the label ourselves.

The `knitLatex` package is useful for generating tables from R output. Other packages can do similar things including the `kable` function in `knitr` which is somewhat simpler but you have less control over the result. If you use `knitLatex` to generate tables, don't forget to include `results="asis"` in the chunk settings.

Chapter 2

Literature Review

This chapter contains a summary of the context in which your research is set.

Imagine you are writing for your fellow PhD students. Topics that are well-known to them do not have to be included here. But things that they may not know about should be included.

Resist the temptation to discuss everything you've read in the last few years. And you are not writing a textbook either. This chapter is meant to provide the background necessary to understand the material in subsequent chapters. Stick to that.

You will need to organize the literature review around themes, and within each theme provide a story explaining the development of ideas to date. In each theme, you should get to the point where your ideas will fit in. But leave your ideas to later chapters. This way it is clear what has been done beforehand, and what new contributions you are making to the research field.

All citations should be done using markdown notation as shown below. This way, your bibliography will be compiled automatically and correctly.

2.1 Exponential smoothing

Exponential smoothing was originally developed in the late 1950s (Brown, [1959](#), [1963](#); Holt, [1957](#); Winters, [1960](#)). Because of their computational simplicity and interpretability, they became widely used in practice.

Empirical studies by Makridakis and Hibon (1979) and Makridakis et al. (1982) found little difference in forecast accuracy between exponential smoothing and ARIMA models. This made the family of exponential smoothing procedures an attractive proposition (see Chatfield et al., 2001).

The methods were less popular in academic circles until Ord, Koehler, and Snyder (1997) introduced a state space formulation of some of the methods, which was extended in Hyndman et al. (2002) to cover the full range of exponential smoothing methods.

Appendix A

Additional stuff

You might put some computer output here, or maybe additional tables.

Note that line 5 must appear before your first appendix. But other appendices can just start like any other chapter.

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