THESIS TITLE

A Thesis

Submitted to the Faculty of Graduate Studies and Research

In Partial Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy

in

Statistics

University of Regina

By

NameName

Regina, Saskatchewan

Month, Year

Abstract

The thesis abstract goes here.

Acknowledgements

Acknowledgements go here.

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Chapter 1

Introduction

To render the file, run “compile.R” from RStudio.

Reference to Chapter 1. Reference to section 1.1. Reference to subsection 1.1.1. When the thesis is “knit” correctly you can also reference other chapters, like Chapter 2. Reference to citation in “book.bib” file, (Dobson & Barnett, 2018). Or like this Dobson & Barnett (2018).

1.1 Section

Reference to Table 1.1.

Reference to Figure 1.1.

Reference to Equation (1.1).

Table 1.1: Relative Efficiency of Unified Estimate for Average

	rho = 0	rho = 0.2	rho = 0.4	rho = 0.6	rho = 0.8
pi = 0.8	1	1.008	1.033	1.078	1.147
pi = 0.6	1	1.016	1.068	1.168	1.344
pi = 0.4	1	1.025	1.106	1.276	1.623
pi = 0.2	1	1.033	1.147	1.404	2.049

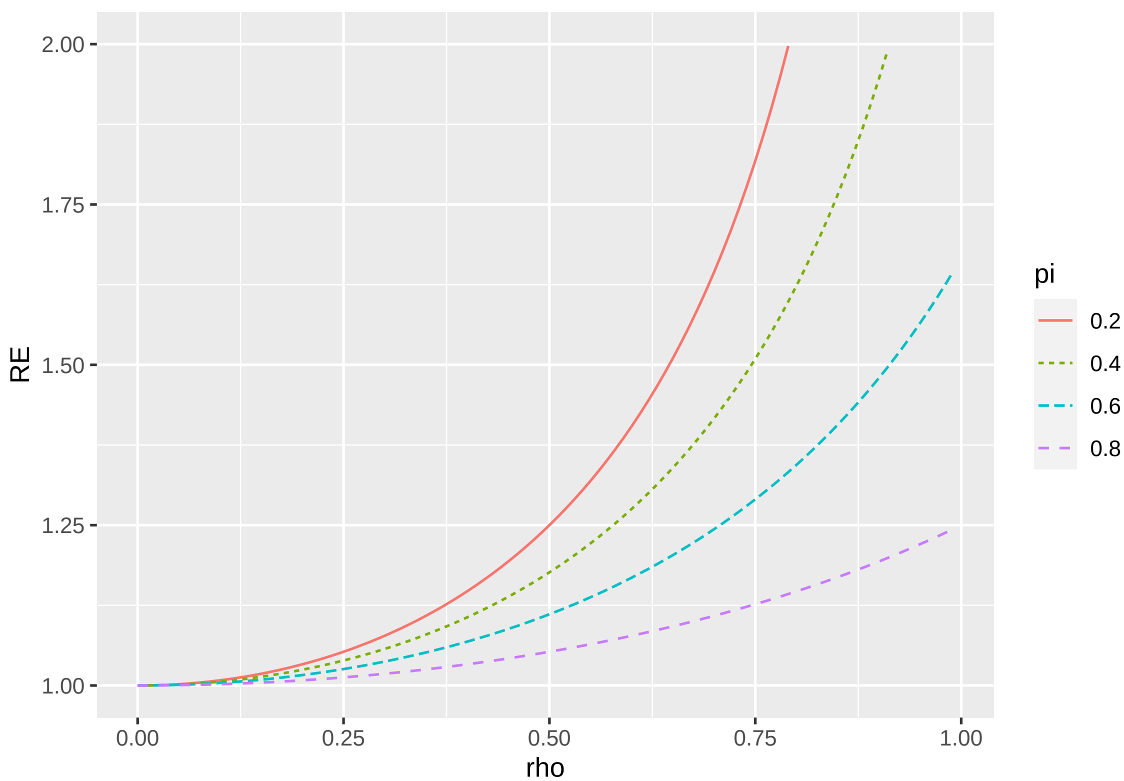

Figure 1.1: Relative Efficiency of Unified Estimate for Average

$$
0 = \frac{1}{n} \sum_{i=1}^{n} \psi(X_i, \hat{\beta}) \tag{1.1}
$$

Equations can also be used without numbering. Using $$ allows RStudio to render it in the editor window.

$$
0 = \frac{1}{n} \sum_{i=1}^{n} \psi(X_i, \hat{\beta})
$$

When writing in RStudio I found it easier to have two copies of the formula in the file, one using "$$" and one using \begin{equation}. That way I could see the rendering of the formula which I found easier to proofread than the raw latex. I "commented out" or deleted the duplicate formula before sending it to my supervisor. ~ Luke T

You can access the special Lemma, Theorem, and Proposition environments as well.

Reference to Lemma 1.1.

Lemma 1.1 (Serfling 1980 Lemma 7.2.1 A)**.** *Let β^* be an isolated root of $\lambda_F(\beta) = 0$. Let $\psi(X, \beta)$ be monotone in β. Then β^* is unique and any solution sequence $\{\hat{\beta}_n\}$ of the empirical equation $\lambda_{F_n}(\beta) = 0$ converges to β^* with probability 1. If, further, $\psi(X, \beta)$ is continuous in β in a neighborhood of β^*, then there exists such a solution sequence.*

Reference to Theorem 1.1.

Theorem 1.1 (Serfling 1980 Theorem 7.2.2 A)**.** *Let β^* be an isolated root of $\lambda_F(\beta) = 0$. Let $\psi(X, \beta)$ be monotone in β. Suppose that $\lambda_F(\beta)$ is differentiable at $\beta = \beta^*$, with $\lambda'_F(\beta^*) \neq 0$. Suppose that $\int \psi^2(X, \beta) dF(x)$ is finite for β in a neighborhood of β^* and is continuous at $\beta = \beta^*$. Then any solution sequence $\hat{\beta}_n$ of the empirical equation*

$\lambda_{F_n}(\beta) = 0$ *satisfies*

$$n^{1/2}(\hat{\beta}_n - \beta^*) \xrightarrow{d} N(0, \frac{\int \psi^2(X, \beta^*) dF(x)}{[\lambda'_F(\beta)]^2}$$

You can include Code Blocks to show the code and R formatting.

```r
# Confirm the theoretical results
library(MASS)
nobs <- 500
cor <- 0.8
pi <- 0.8 # pi is observation probability
gen_dat <- function(nobs,cor,pi) {
  Sigma <- matrix(data = c(1,cor,cor,1),
                  nrow = 2, ncol = 2)
  dat <- mvrnorm(n = nobs, mu = c(0,0), Sigma = Sigma)
  dat[rbinom(nobs,1,pi) == 0,2] <- NA
  return(data.frame(x = dat[,1],
                    y = dat[,2]))
}
```

1.1.1 Subsection

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Chapter 2

Background

A complicated table, for example.

Table 2.1: Simulation Results

N		$\|Bias\|$ β_1	β_2	β_3	$s.d.$ β_1	β_2	β_3	RMSE β_1	β_2	β_3	$95\%CP$ β_1	β_2	β_3	$s.e.$ β_1	β_2	β_3
(A) The missingness is independent of the failure time																
500	full	2	5	6	156	192	130	156	192	131	96.5	94.8	94.4	163	186	130
	CC	11	15	14	245	278	191	245	279	191	94.2	94.8	94.5	242	274	191
	WCC	7	15	14	252	280	194	252	280	194	93.2	93.7	94.0	244	275	192
	MI	2	15	13	168	264	185	168	264	186	96.7	93.5	93.0	175	251	180
	UE	16	13	13	174	256	179	175	256	180	95.1	93.0	93.7	174	248	177
	UE*	10	19	15	176	258	182	176	259	182	95.0	94.0	93.8	181	257	184
	UE^{cc}	11	13	13	173	255	177	173	255	178	95.3	93.6	94.1	173	246	176
	UE^{cc*}	12	18	15	174	258	180	174	259	180	96.1	93.3	94.7	181	255	183
1000	full	1	5	4	113	132	92	113	132	92	95.1	95.6	94.9	114	131	92
	CC	6	10	5	159	195	130	159	195	130	95.7	94.4	95.2	168	192	134
	WCC	6	10	4	165	196	132	165	196	132	95.4	93.8	95.1	170	192	134
	MI	4	11	6	121	181	127	121	181	128	95.0	93.6	94.0	122	178	127
	UE	13	10	6	125	182	126	125	182	126	93.5	93.5	94.3	122	174	124
	UE*	9	12	7	126	183	126	126	183	126	94.4	94.5	94.8	125	176	126
	UE^{cc}	10	11	7	125	180	125	125	181	125	92.9	93.3	94.4	122	173	124
	UE^{cc*}	11	13	7	127	180	125	127	181	125	94.2	94.2	94.8	125	175	125
(B) The missingness depends on the failure time																
500	full	2	5	6	156	192	130	156	192	131	96.5	94.8	94.4	163	186	130
	CC	136	65	38	195	233	158	237	242	163	89.9	92.8	93.5	197	225	157
	WCC	7	10	10	187	227	154	187	227	154	96.0	93.4	94.6	194	219	153
	MI	3	9	8	157	215	147	157	215	147	96.6	94.0	94.8	166	210	148
	UE	14	10	9	161	216	149	162	216	149	96.6	94.4	94.8	167	215	153
	UE*	4	8	9	163	219	150	163	219	151	95.9	94.0	94.2	167	211	150
	UE^{cc}	27	50	36	164	223	153	166	228	157	95.9	93.5	93.3	166	214	151
	UE^{cc*}	18	51	37	167	227	156	168	233	160	95.6	93.3	93.6	170	218	154
1000	full	1	5	4	113	132	92	113	132	92	95.1	95.6	94.9	114	131	92
	CC	136	59	30	136	160	111	192	170	115	83.5	94.1	95.1	138	158	110
	WCC	8	5	2	132	155	107	132	155	107	95.9	94.8	95.3	136	154	107
	MI	2	6	5	114	149	105	114	149	105	95.7	95.0	95.1	116	147	104
	UE	7	5	3	116	149	105	116	149	105	95.0	95.9	95.5	117	151	108
	UE*	3	3	2	117	150	105	117	150	105	95.0	95.3	94.5	116	147	104
	UE^{cc}	24	44	30	118	153	108	121	160	112	94.4	94.0	94.2	117	150	107
	UE^{cc*}	15	47	33	118	156	110	119	163	115	95.2	93.1	93.1	118	151	106

Entries of absolute value of bias ($|bias|$), empirical standard deviation ($s.d.$), square root of MSE (RMSE) and standard error ($s.e.$) are multiplied by 1000, and coverage rates of 95% confidence interval ($95\%CP$) are multiplied by 100.

Chapter 3

Conclusion and Future Work

The end!

References

Dobson, A. J., & Barnett, A. G. (2018). *An introduction to generalized linear models.* CRC Press.

Appendix A

Proofs

A.1 Proof of Optimality

The asymptotic variance of an alternative estimator $\tilde{\beta} = \hat{\beta} - (\Sigma_{12}\Sigma_{22}^{-1} + B)(\hat{\gamma} - \hat{\gamma}')$ with B a conformable matrix, can be found as

$$
\begin{aligned}
V[\tilde{\beta}] =& V[\hat{\beta} + (-\Sigma_{12}\Sigma_{22}^{-1} - B)(\hat{\gamma} - \hat{\gamma}')] \\
=& V[\hat{\beta}] + Cov[\hat{\beta}, (-\Sigma_{12}\Sigma_{22}^{-1} - B)(\hat{\gamma} - \hat{\gamma}')] + \\
& Cov[(-\Sigma_{12}\Sigma_{22}^{-1} - B)(\hat{\gamma} - \hat{\gamma}'), \hat{\beta}] + V[(-\Sigma_{12}\Sigma_{22}^{-1} - B)(\hat{\gamma} - \hat{\gamma}')] \\
=& V[\hat{\beta}] + Cov[\hat{\beta}, (\hat{\gamma} - \hat{\gamma}')](-\Sigma_{12}\Sigma_{22}^{-1} - B)^T + \\
& (-\Sigma_{12}\Sigma_{22}^{-1} - B)Cov[(\hat{\gamma} - \hat{\gamma}'), \hat{\beta}] + \\
& (-\Sigma_{12}\Sigma_{22}^{-1} - B)V[(\hat{\gamma} - \hat{\gamma}')](-\Sigma_{12}\Sigma_{22}^{-1} - B)^T \\
=& \Sigma_{11} + \Sigma_{12}(-\Sigma_{12}\Sigma_{22}^{-1} - B)^T + \\
& (-\Sigma_{12}\Sigma_{22}^{-1} - B)\Sigma_{21} + \\
& (-\Sigma_{12}\Sigma_{22}^{-1} - B)\Sigma_{22}(-\Sigma_{12}\Sigma_{22}^{-1} - B)^T \\
=& \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21} + B\Sigma_{22}B^T
\end{aligned}
$$

A.2 Example of Efficiency of Unified Estimate

The remaining details for the example are now given. For the estimating equations

$$S(\theta, X) = \begin{pmatrix} R(y-\beta) \\ R(x-\gamma) \\ (x-\gamma') \end{pmatrix}$$

We did some math.

Appendix B

R Code

Any extra code you want to include could go here.

```
set.seed(123)

mean(rnorm(n = 20))
```