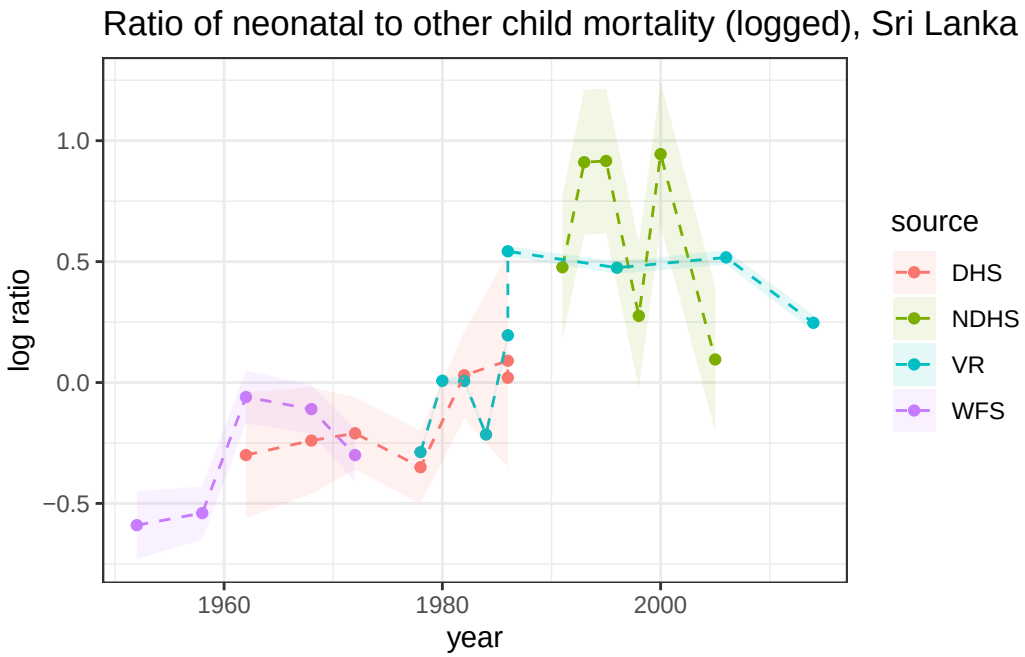
Week 10: Temporal data

26/03/23

Child mortality in Sri Lanka

In this lab you will be fitting a couple of different models to the data about child mortality in Sri Lanka, which was used in the lecture. Here's the data and the plot from the lecture:

```
library(tidyverse)
library(here)
library(rstan)
library(tidybayes)

lka <- read_csv(here("data/lka.csv"))
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka", y = "log
```



Fitting a linear model

Let's firstly fit a linear model in time to these data. Here's the code to do this:

```
observed_years <- lka$year
years <- min(observed_years):max(observed_years)
nyears <- length(years)

stan_data <- list(y = lka$logit_ratio, year_i = observed_years - years[1]+1,
                  T = nyears, years = years, N = length(observed_years),
                  mid_year = mean(years), se = lka$se)

mod <- stan(data = stan_data,
             file = here("code/models/lka_linear_me.stan"),
            seed = 0)
```

```
SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
Chain 1:
Chain 1: Gradient evaluation took 1.8e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.18 seconds.
```

```
Chain 1: Adjust your expectations accordingly!
Chain 1:
Chain 1:
Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 1:
Chain 1:  Elapsed Time: 0.049 seconds (Warm-up)
Chain 1:                0.023 seconds (Sampling)
Chain 1:                0.072 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 3e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.03 seconds.
Chain 2: Adjust your expectations accordingly!
Chain 2:
Chain 2:
Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 2:
Chain 2:  Elapsed Time: 0.033 seconds (Warm-up)
Chain 2:                0.025 seconds (Sampling)
```

```
Chain 2:                0.058 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 3e-06 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.03 seconds.
Chain 3: Adjust your expectations accordingly!
Chain 3:
Chain 3:
Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 3:
Chain 3:  Elapsed Time: 0.033 seconds (Warm-up)
Chain 3:                0.025 seconds (Sampling)
Chain 3:                0.058 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 4e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.04 seconds.
Chain 4: Adjust your expectations accordingly!
Chain 4:
Chain 4:
Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
```

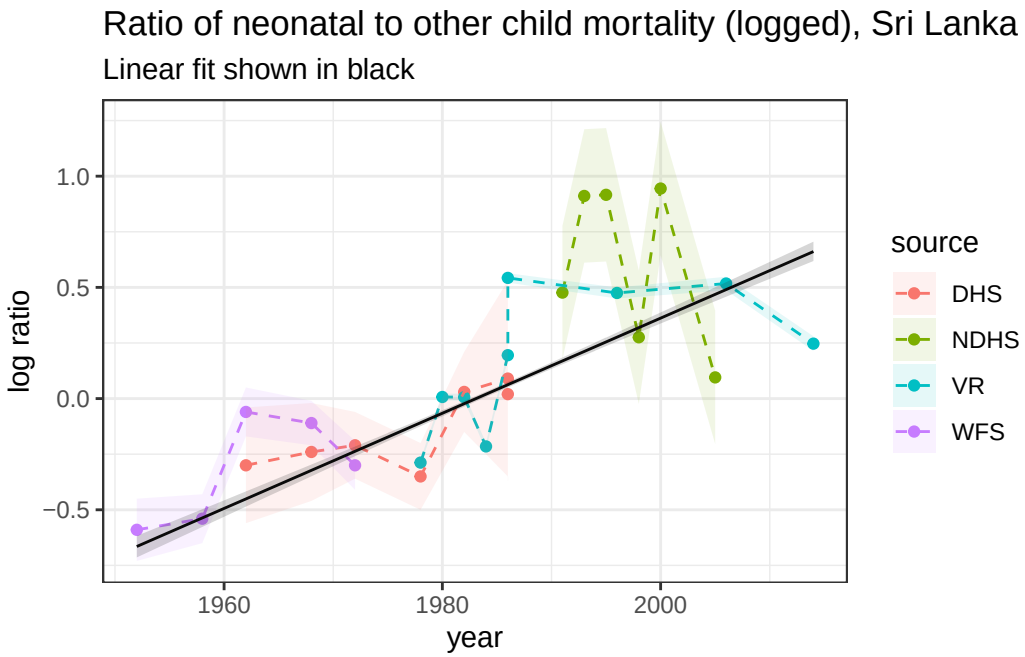
```
Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 4:
Chain 4:  Elapsed Time: 0.031 seconds (Warm-up)
Chain 4:                0.026 seconds (Sampling)
Chain 4:                0.057 seconds (Total)
Chain 4:
```

Extract the results:

```
res <- mod %>%
  gather_draws(mu[t]) %>%
  median_qi() %>%
  mutate(year = years[t])
```

Plot the results:

```
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  geom_line(data = res, aes(year, .value)) +
  geom_ribbon(data = res, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
  theme_bw()+
  labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka",
       y = "log ratio", subtitle = "Linear fit shown in black")
```



Question 1

Project the linear model above out to 2023 by adding a `generated quantities` block in Stan (do the projections based on the expected value μ). Plot the resulting projections on a graph similar to that above.

```
observed_years <- lka$year
years <- min(observed_years):max(observed_years)
nyears <- length(years)

stan_data <- list(y = lka$logit_ratio, year_i = observed_years - years[1]+1,
                  T = nyears, years = years, N = length(observed_years),
                  mid_year = mean(years), se = lka$se,
                  P = 9)

mod2 <- stan(data = stan_data,
             file = here("code/models/lab10_1.stan"),
             seed = 0)
```

```
SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
```

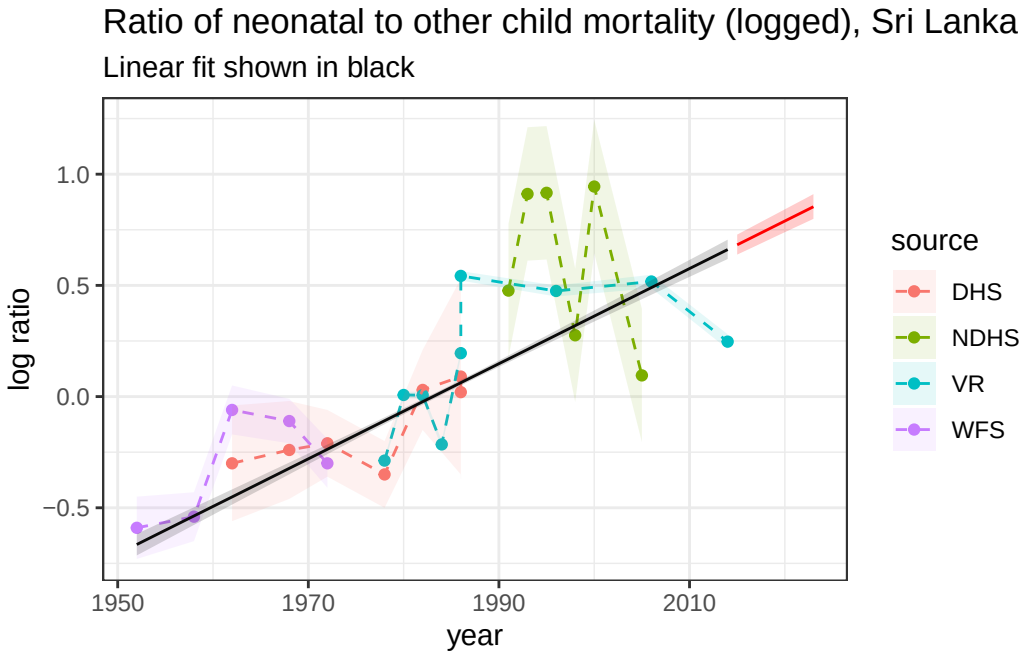
```
Chain 1:
Chain 1: Gradient evaluation took 1.6e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.16 seconds.
Chain 1: Adjust your expectations accordingly!
Chain 1:
Chain 1:
Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 1:
Chain 1:  Elapsed Time: 0.033 seconds (Warm-up)
Chain 1:                0.024 seconds (Sampling)
Chain 1:                0.057 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 4e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.04 seconds.
Chain 2: Adjust your expectations accordingly!
Chain 2:
Chain 2:
Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
```

```
Chain 2:
Chain 2:  Elapsed Time: 0.029 seconds (Warm-up)
Chain 2:                0.024 seconds (Sampling)
Chain 2:                0.053 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 3e-06 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.03 seconds.
Chain 3: Adjust your expectations accordingly!
Chain 3:
Chain 3:
Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 3:
Chain 3:  Elapsed Time: 0.032 seconds (Warm-up)
Chain 3:                0.03 seconds (Sampling)
Chain 3:                0.062 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 3e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.03 seconds.
Chain 4: Adjust your expectations accordingly!
Chain 4:
Chain 4:
Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
```

```
Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 4:
Chain 4:  Elapsed Time: 0.031 seconds (Warm-up)
Chain 4:                0.023 seconds (Sampling)
Chain 4:                0.054 seconds (Total)
Chain 4:
```

```r
res1a <- mod2 %>%
  gather_draws(mu[t]) %>%
  median_qi() %>%
  mutate(year = years[t])


res1b <- mod2 %>%
  gather_draws(mu_p[p]) %>%
  median_qi() %>%
  mutate(year = years[nyears]+p)
```

```r
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  geom_line(data = res1a, aes(year, .value)) +
  geom_ribbon(data = res1a, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
  geom_line(data = res1b, aes(year, .value), col = "red") +
  geom_ribbon(data = res1b, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi
  theme_bw()+
  labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka",
       y = "log ratio", subtitle = "Linear fit shown in black")
```



Random walks

Question 2

Code up and estimate a first order random walk model to fit to the Sri Lankan data, taking into account measurement error, and project out to 2023.

```
mod3 <- stan(data = stan_data,
             file = here("code/models/lab10_2.stan"),
             seed = 0)
```

```
SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
Chain 1:
Chain 1: Gradient evaluation took 2.5e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.25 seconds.
Chain 1: Adjust your expectations accordingly!
Chain 1:
Chain 1:
Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
```

```
Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 1:
Chain 1:  Elapsed Time: 0.205 seconds (Warm-up)
Chain 1:                0.178 seconds (Sampling)
Chain 1:                0.383 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 8e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.08 seconds.
Chain 2: Adjust your expectations accordingly!
Chain 2:
Chain 2:
Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 2:
Chain 2:  Elapsed Time: 0.227 seconds (Warm-up)
Chain 2:                0.189 seconds (Sampling)
Chain 2:                0.416 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
```

```
Chain 3: Gradient evaluation took 7e-06 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
Chain 3: Adjust your expectations accordingly!
Chain 3:
Chain 3:
Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 3:
Chain 3:  Elapsed Time: 0.242 seconds (Warm-up)
Chain 3:                0.215 seconds (Sampling)
Chain 3:                0.457 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 5e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.05 seconds.
Chain 4: Adjust your expectations accordingly!
Chain 4:
Chain 4:
Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 4:
```

```
Chain 4:  Elapsed Time: 0.269 seconds (Warm-up)
Chain 4:                0.176 seconds (Sampling)
Chain 4:                0.445 seconds (Total)
Chain 4:
```

```
mod3
```

```
Inference for Stan model: anon_model.
4 chains, each with iter=2000; warmup=1000; thin=1;
post-warmup draws per chain=1000, total post-warmup draws=4000.
```

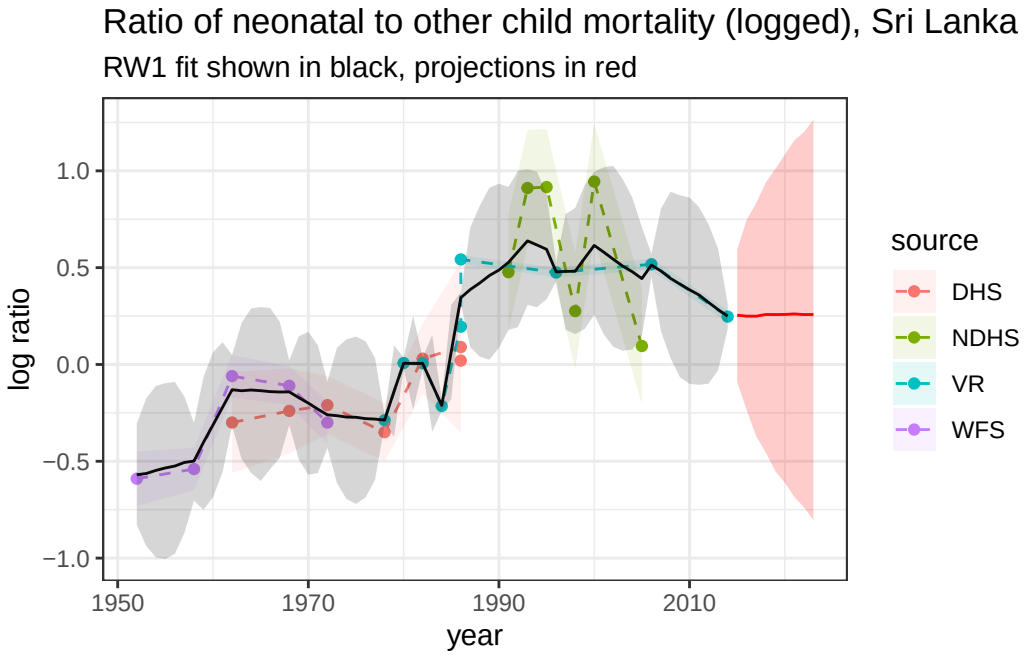
	mean	se_mean	sd	2.5%	25%	50%	75%	97.5%	n_eff	Rhat
mu[1]	-0.57	0.00	0.13	-0.83	-0.66	-0.57	-0.48	-0.31	4090	1
mu[2]	-0.56	0.00	0.19	-0.94	-0.69	-0.56	-0.43	-0.17	3234	1
mu[3]	-0.55	0.00	0.22	-1.00	-0.69	-0.55	-0.40	-0.11	2918	1
mu[4]	-0.54	0.00	0.23	-1.00	-0.69	-0.53	-0.39	-0.10	2875	1
mu[5]	-0.52	0.00	0.22	-0.98	-0.67	-0.52	-0.38	-0.09	2809	1
mu[6]	-0.51	0.00	0.18	-0.87	-0.63	-0.51	-0.39	-0.17	3368	1
mu[7]	-0.50	0.00	0.10	-0.70	-0.57	-0.50	-0.43	-0.30	4203	1
mu[8]	-0.40	0.00	0.17	-0.75	-0.51	-0.40	-0.29	-0.07	3913	1
mu[9]	-0.31	0.00	0.19	-0.69	-0.43	-0.31	-0.19	0.06	3787	1
mu[10]	-0.22	0.00	0.17	-0.56	-0.33	-0.22	-0.11	0.11	4266	1
mu[11]	-0.13	0.00	0.09	-0.32	-0.20	-0.13	-0.07	0.05	3825	1
mu[12]	-0.14	0.00	0.18	-0.49	-0.25	-0.14	-0.02	0.21	3255	1
mu[13]	-0.14	0.00	0.22	-0.56	-0.28	-0.13	0.01	0.29	2962	1
mu[14]	-0.14	0.00	0.22	-0.60	-0.28	-0.14	0.01	0.30	2906	1
mu[15]	-0.14	0.00	0.21	-0.54	-0.28	-0.14	0.00	0.29	2870	1
mu[16]	-0.14	0.00	0.18	-0.48	-0.25	-0.14	-0.03	0.22	3559	1
mu[17]	-0.14	0.00	0.08	-0.31	-0.20	-0.14	-0.08	0.02	4048	1
mu[18]	-0.17	0.00	0.16	-0.49	-0.28	-0.17	-0.07	0.15	4115	1
mu[19]	-0.20	0.00	0.19	-0.57	-0.32	-0.20	-0.08	0.17	3915	1
mu[20]	-0.23	0.00	0.17	-0.56	-0.34	-0.23	-0.13	0.10	4711	1
mu[21]	-0.26	0.00	0.09	-0.43	-0.32	-0.26	-0.20	-0.09	5448	1
mu[22]	-0.27	0.00	0.17	-0.61	-0.38	-0.26	-0.16	0.09	3730	1
mu[23]	-0.27	0.00	0.21	-0.70	-0.40	-0.27	-0.14	0.13	3334	1
mu[24]	-0.28	0.00	0.22	-0.72	-0.41	-0.27	-0.14	0.14	3349	1
mu[25]	-0.28	0.00	0.20	-0.69	-0.41	-0.28	-0.15	0.12	3546	1
mu[26]	-0.28	0.00	0.16	-0.60	-0.38	-0.28	-0.18	0.03	4366	1
mu[27]	-0.29	0.00	0.01	-0.31	-0.30	-0.29	-0.28	-0.26	5851	1
mu[28]	-0.14	0.00	0.12	-0.37	-0.22	-0.14	-0.06	0.10	5958	1
mu[29]	0.01	0.00	0.02	-0.02	0.00	0.01	0.02	0.04	6682	1
mu[30]	0.01	0.00	0.12	-0.23	-0.07	0.01	0.08	0.25	5771	1

mu[31]	0.01	0.00	0.02	-0.02	-0.01	0.01	0.02	0.04	6399	1
mu[32]	-0.10	0.00	0.12	-0.35	-0.18	-0.10	-0.02	0.15	6307	1
mu[33]	-0.21	0.00	0.02	-0.24	-0.22	-0.21	-0.20	-0.18	5047	1
mu[34]	0.07	0.00	0.12	-0.18	-0.01	0.07	0.15	0.31	6804	1
mu[35]	0.34	0.00	0.01	0.32	0.34	0.34	0.35	0.37	5966	1
mu[36]	0.39	0.00	0.16	0.09	0.28	0.39	0.49	0.71	3663	1
mu[37]	0.42	0.00	0.20	0.04	0.29	0.42	0.56	0.82	3122	1
mu[38]	0.46	0.00	0.22	0.02	0.32	0.46	0.60	0.91	2820	1
mu[39]	0.49	0.00	0.22	0.09	0.35	0.49	0.64	0.93	2877	1
mu[40]	0.53	0.00	0.19	0.18	0.40	0.53	0.66	0.92	3008	1
mu[41]	0.59	0.00	0.20	0.19	0.46	0.58	0.72	1.00	2712	1
mu[42]	0.64	0.00	0.18	0.31	0.52	0.64	0.76	1.01	2682	1
mu[43]	0.62	0.00	0.18	0.30	0.50	0.62	0.74	0.99	2910	1
mu[44]	0.60	0.00	0.14	0.34	0.50	0.59	0.69	0.88	3301	1
mu[45]	0.48	0.00	0.02	0.43	0.46	0.48	0.49	0.53	5142	1
mu[46]	0.48	0.00	0.15	0.18	0.39	0.48	0.58	0.78	4832	1
mu[47]	0.48	0.00	0.16	0.16	0.38	0.48	0.59	0.81	3628	1
mu[48]	0.55	0.00	0.19	0.18	0.43	0.55	0.68	0.93	3173	1
mu[49]	0.62	0.00	0.19	0.26	0.49	0.61	0.75	1.00	2649	1
mu[50]	0.58	0.00	0.22	0.16	0.44	0.58	0.72	1.02	2598	1
mu[51]	0.55	0.00	0.24	0.09	0.39	0.54	0.70	1.03	2890	1
mu[52]	0.51	0.00	0.22	0.07	0.36	0.51	0.65	0.96	2906	1
mu[53]	0.48	0.00	0.20	0.08	0.34	0.48	0.61	0.86	3205	1
mu[54]	0.44	0.00	0.14	0.15	0.34	0.44	0.54	0.71	3753	1
mu[55]	0.51	0.00	0.03	0.45	0.49	0.51	0.53	0.57	5898	1
mu[56]	0.48	0.00	0.16	0.17	0.38	0.48	0.58	0.80	3805	1
mu[57]	0.45	0.00	0.21	0.03	0.32	0.44	0.58	0.89	3185	1
mu[58]	0.41	0.00	0.23	-0.07	0.27	0.41	0.57	0.87	2665	1
mu[59]	0.38	0.00	0.24	-0.10	0.23	0.39	0.54	0.86	2938	1
mu[60]	0.35	0.00	0.23	-0.10	0.20	0.36	0.50	0.81	2733	1
mu[61]	0.32	0.00	0.21	-0.10	0.19	0.32	0.45	0.72	3063	1
mu[62]	0.28	0.00	0.16	-0.03	0.18	0.28	0.39	0.60	3716	1
mu[63]	0.25	0.00	0.03	0.18	0.23	0.25	0.27	0.32	5483	1
sigma	0.17	0.00	0.04	0.11	0.14	0.16	0.19	0.26	522	1
mu_p[1]	0.25	0.00	0.17	-0.09	0.14	0.25	0.36	0.59	3668	1
mu_p[2]	0.25	0.00	0.25	-0.24	0.09	0.25	0.41	0.75	3510	1
mu_p[3]	0.25	0.00	0.30	-0.37	0.06	0.25	0.44	0.83	3902	1
mu_p[4]	0.25	0.01	0.35	-0.45	0.03	0.26	0.48	0.94	4014	1
mu_p[5]	0.25	0.01	0.39	-0.55	0.00	0.26	0.50	1.01	4036	1
mu_p[6]	0.25	0.01	0.42	-0.61	-0.01	0.26	0.53	1.09	4065	1
mu_p[7]	0.25	0.01	0.46	-0.68	-0.04	0.26	0.55	1.16	4180	1
mu_p[8]	0.26	0.01	0.49	-0.74	-0.06	0.26	0.57	1.20	4135	1
mu_p[9]	0.25	0.01	0.52	-0.80	-0.07	0.26	0.58	1.26	4097	1

```
lp__    -6.79    0.58 12.11 -32.48 -14.61 -5.99  1.99 14.34   439    1

Samples were drawn using NUTS(diag_e) at Sun Mar 26 13:21:45 2023.
For each parameter, n_eff is a crude measure of effective sample size,
and Rhat is the potential scale reduction factor on split chains (at
convergence, Rhat=1).
```

```
res2a <- mod3 %>%
  gather_draws(mu[t]) %>%
  median_qi() %>%
  mutate(year = years[t])


res2b <- mod3 %>%
  gather_draws(mu_p[p]) %>%
  median_qi() %>%
  mutate(year = years[nyears]+p)
```

```
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  geom_line(data = res2a, aes(year, .value)) +
  geom_ribbon(data = res2a, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
  geom_line(data = res2b, aes(year, .value), col = "red") +
  geom_ribbon(data = res2b, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi
  theme_bw()+
  labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka",
       y = "log ratio", subtitle = "RW1 fit shown in black, projections in red")
```



Question 3

Now alter your model above to estimate and project a second-order random walk model (RW2).

```
mod4 <- stan(data = stan_data,
             file = here("code/models/lab10_3.stan"),
             seed = 0)
```

```
SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
Chain 1:
Chain 1: Gradient evaluation took 2.8e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.28 seconds.
Chain 1: Adjust your expectations accordingly!
Chain 1:
Chain 1:
Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
```

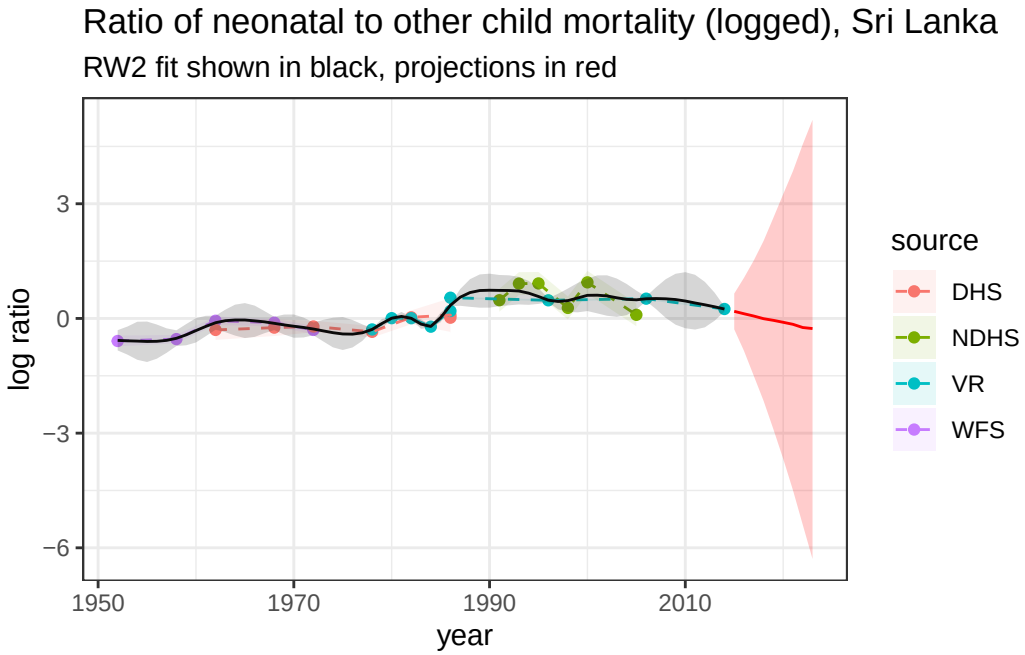
```
Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 1:
Chain 1:  Elapsed Time: 0.688 seconds (Warm-up)
Chain 1:                0.691 seconds (Sampling)
Chain 1:                1.379 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 7e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
Chain 2: Adjust your expectations accordingly!
Chain 2:
Chain 2:
Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 2:
Chain 2:  Elapsed Time: 0.659 seconds (Warm-up)
Chain 2:                0.58 seconds (Sampling)
Chain 2:                1.239 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 5e-05 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.5 seconds.
```

```
Chain 3: Adjust your expectations accordingly!
Chain 3:
Chain 3:
Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 3:
Chain 3:  Elapsed Time: 0.679 seconds (Warm-up)
Chain 3:                0.657 seconds (Sampling)
Chain 3:                1.336 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 7e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
Chain 4: Adjust your expectations accordingly!
Chain 4:
Chain 4:
Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 4:
Chain 4:  Elapsed Time: 0.654 seconds (Warm-up)
Chain 4:                0.659 seconds (Sampling)
```

```
Chain 4:                1.313 seconds (Total)
Chain 4:
```

```
res3a <- mod4 %>%
  gather_draws(mu[t]) %>%
  median_qi() %>%
  mutate(year = years[t])

res3b <- mod4 %>%
  gather_draws(mu_p[p]) %>%
  median_qi() %>%
  mutate(year = years[nyears]+p)
```

```
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  geom_line(data = res3a, aes(year, .value)) +
  geom_ribbon(data = res3a, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
  geom_line(data = res3b, aes(year, .value), col = "red") +
  geom_ribbon(data = res3b, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi
  theme_bw()+
  labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka",
       y = "log ratio", subtitle = "RW2 fit shown in black, projections in red")
```

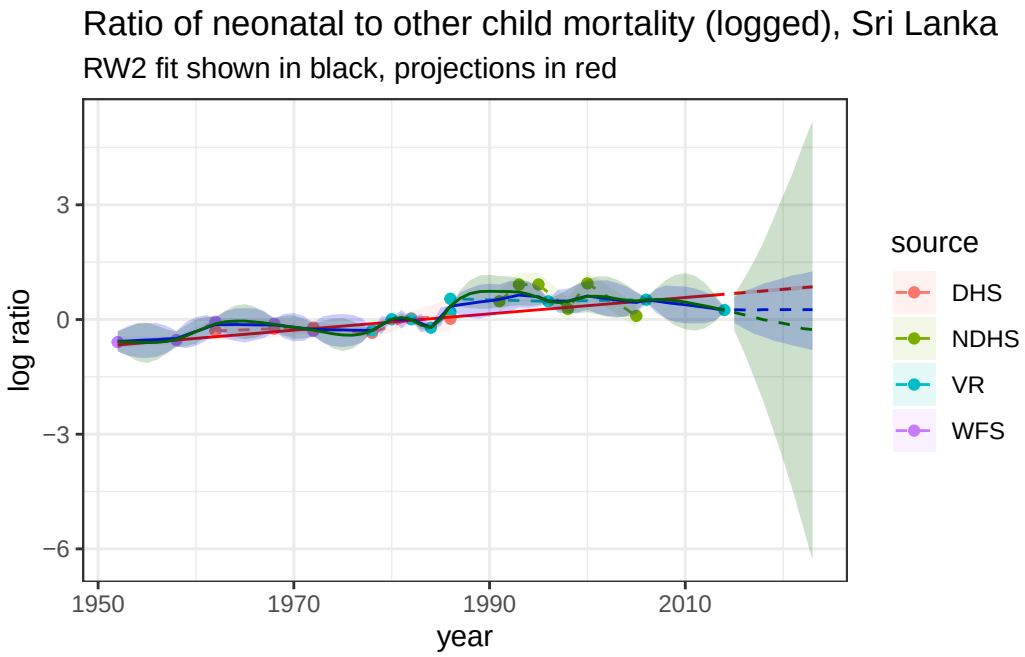


Question 4

Run the first order and second order random walk models, including projections out to 2023. Compare these estimates with the linear fit by plotting everything on the same graph.

```
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  # Linear Model
  geom_line(data = res1a, aes(year, .value), col = "red") +
  geom_ribbon(data = res1a, aes(y = .value, ymin = .lower, ymax = .upper), fill = "red", a
  geom_line(data = res1b, aes(year, .value), col = "red", lty = "dashed") +
  geom_ribbon(data = res1b, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi

  # Random Walk 1
  geom_line(data = res2a, aes(year, .value), col = "blue") +
  geom_ribbon(data = res2a, aes(y = .value, ymin = .lower, ymax = .upper), fill = "blue",
```

```
  geom_line(data = res2b, aes(year, .value), col = "blue", lty = "dashed") +
  geom_ribbon(data = res2b, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi

  # Random Walk 2
  geom_line(data = res3a, aes(year, .value), col = "darkgreen") +
  geom_ribbon(data = res3a, aes(y = .value, ymin = .lower, ymax = .upper), fill = "darkgre
  geom_line(data = res3b, aes(year, .value), col = "darkgreen", lty = "dashed") +
  geom_ribbon(data = res3b, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi
  theme_bw()+
  labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka",
       y = "log ratio", subtitle = "RW2 fit shown in black, projections in red")
```



Question 5

Rerun the RW2 model excluding the VR data. Briefly comment on the differences between the two data situations.

```
lka_noVR <- lka %>%
  filter(source != "VR")
```

```r
observed_years <- lka_noVR$year
years <- min(observed_years):max(observed_years)
nyears <- length(years)

stan_data <- list(y = lka_noVR$logit_ratio, year_i = observed_years - years[1]+1,
                  T = nyears, years = years, N = length(observed_years),
                  mid_year = mean(years), se = lka_noVR$se,
                  P = 9)

mod5 <- stan(data = stan_data,
             file = here("code/models/lab10_3.stan"))
```

```
SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
Chain 1:
Chain 1: Gradient evaluation took 1e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
Chain 1: Adjust your expectations accordingly!
Chain 1:
Chain 1:
Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 1:
Chain 1:  Elapsed Time: 1.932 seconds (Warm-up)
Chain 1:                1.355 seconds (Sampling)
Chain 1:                3.287 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 8e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.08 seconds.
```

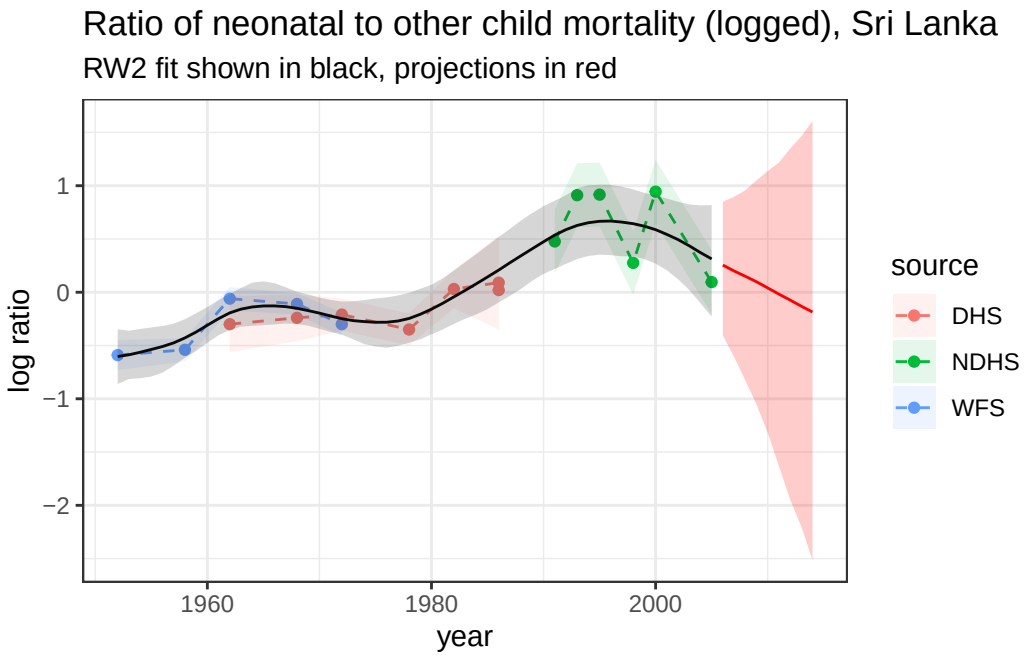
```
Chain 2: Adjust your expectations accordingly!
Chain 2:
Chain 2:
Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 2:
Chain 2:  Elapsed Time: 1.598 seconds (Warm-up)
Chain 2:                1.387 seconds (Sampling)
Chain 2:                2.985 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 6e-06 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.06 seconds.
Chain 3: Adjust your expectations accordingly!
Chain 3:
Chain 3:
Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 3:
Chain 3:  Elapsed Time: 1.778 seconds (Warm-up)
Chain 3:                1.871 seconds (Sampling)
```

```
Chain 3:                3.649 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 7e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
Chain 4: Adjust your expectations accordingly!
Chain 4:
Chain 4:
Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 4:
Chain 4:  Elapsed Time: 1.981 seconds (Warm-up)
Chain 4:                1.328 seconds (Sampling)
Chain 4:                3.309 seconds (Total)
Chain 4:
```

```r
res <- mod5 %>%
  gather_draws(mu[t]) %>%
  median_qi() %>%
  mutate(year = years[t])


res_p <- mod5 %>%
  gather_draws(mu_p[p]) %>%
  median_qi() %>%
  mutate(year = years[nyears]+p)
```

```r
ggplot(lka_noVR, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
```

```
geom_line(aes( color = source), lty = 2) +
geom_ribbon(aes(ymin = logit_ratio - se,
                ymax = logit_ratio + se,
                fill =  source), alpha = 0.1) +
theme_bw()+
geom_line(data = res, aes(year, .value)) +
geom_ribbon(data = res, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
geom_line(data = res_p, aes(year, .value), col = "red") +
geom_ribbon(data = res_p, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2, fi
theme_bw()+
labs(title = "Ratio of neonatal to other child mortality (logged), Sri Lanka",
     y = "log ratio", subtitle = "RW2 fit shown in black, projections in red")
```



When we exclude the VR data, we lose a lot of data in the 2000s. For instance, the data no longer goes to 2014, and instead ends at 2005. Therefore there is less information about recent time series trends when we extrapolate outwards.

Question 6

Briefly comment on which model you think is most appropriate, or an alternative model that would be more appropriate in this context.

Of the models we have tested, the linear model appears to actually do the best in looking at the growth of the logarithm of the ratio. The data grows, and so the linear model is the only one that follows this trend well. An issue with linear models is the unrestricted range, which would not be practical in this example. However, a more specified time series model, like a more complicated AR, MA, might be prudent to try on stationary residuals. This is because a first-order or second-order assumption is quite a restrictive assumption that might not be great for the purposes of modeling child mortality. In particular, it's hard to see why Sri Lankan child mortality would be markov of the first order, as there might be more long-term trends that we miss out on.