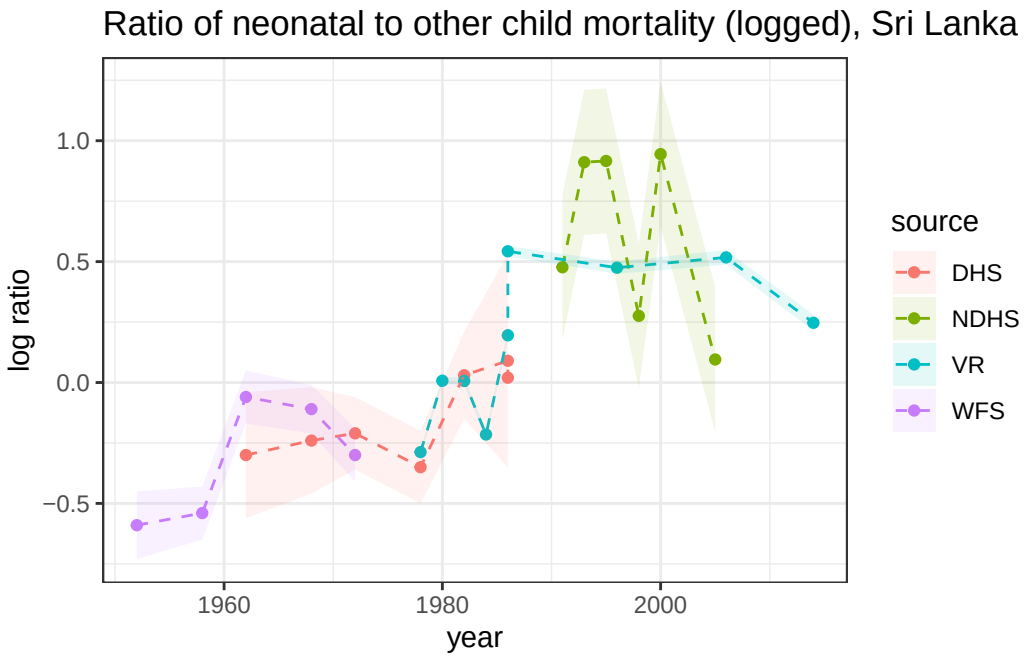
Week 10: Temporal data

23/03/23

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 1.7e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.17 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: 0.026 seconds (Warm-up)
Chain 1:                0.022 seconds (Sampling)
Chain 1:                0.048 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: 0.027 seconds (Warm-up)
Chain 2:                0.021 seconds (Sampling)
```

```
Chain 2:                0.048 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 4e-06 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.04 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: 0.03 seconds (Warm-up)
Chain 3:                0.026 seconds (Sampling)
Chain 3:                0.056 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)
```

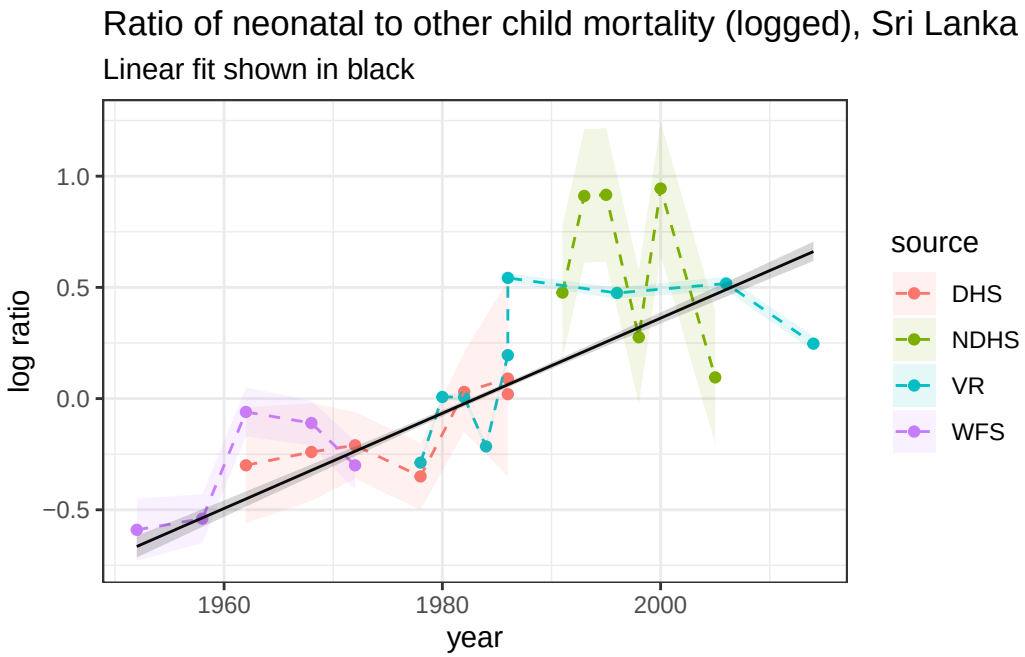
```
Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 4:
Chain 4:  Elapsed Time: 0.026 seconds (Warm-up)
Chain 4:                0.023 seconds (Sampling)
Chain 4:                0.049 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).
```

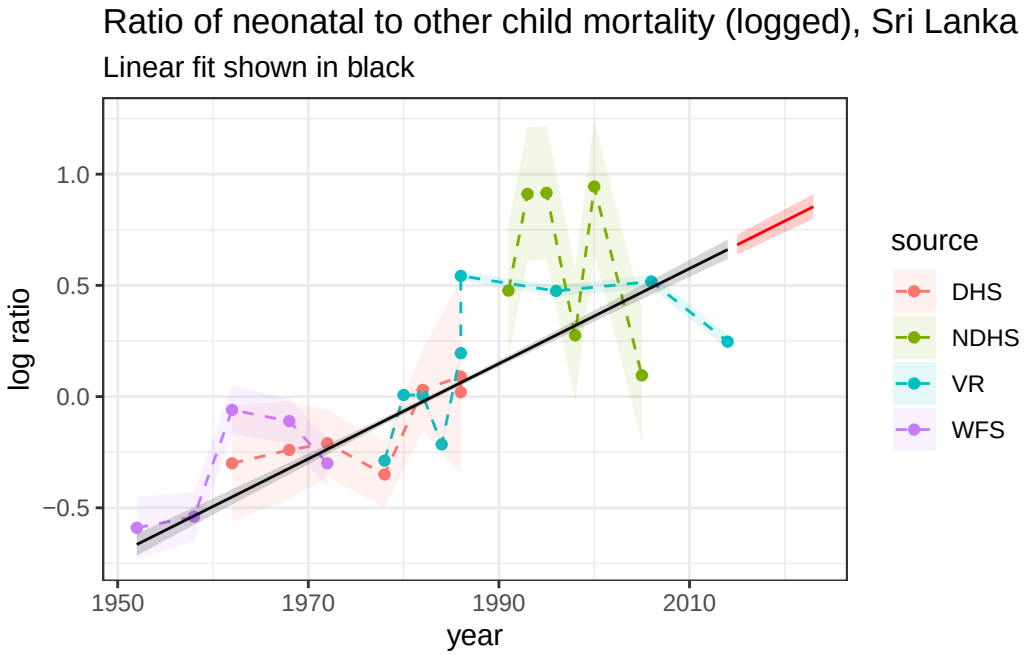
```
Chain 1:
Chain 1: Gradient evaluation took 1.7e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.17 seconds.
Chain 1: Adjust your expectations accordingly!
Chain 1:
Chain 1:
Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
Chain 1: Iteration:  200 / 2000 [ 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: 0.027 seconds (Warm-up)
Chain 1:                0.023 seconds (Sampling)
Chain 1:                0.05 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 5e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.05 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: 0.028 seconds (Warm-up)
Chain 2:                0.023 seconds (Sampling)
Chain 2:                0.051 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: 0.03 seconds (Warm-up)
Chain 3:                0.025 seconds (Sampling)
Chain 3:                0.055 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: 0.027 seconds (Warm-up)
Chain 4:                0.022 seconds (Sampling)
Chain 4:                0.049 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 3.5e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.35 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: 0.17 seconds (Warm-up)
Chain 1:                0.141 seconds (Sampling)
Chain 1:                0.311 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: 0.176 seconds (Warm-up)
Chain 2:                0.156 seconds (Sampling)
Chain 2:                0.332 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: 0.173 seconds (Warm-up)
Chain 3:                0.157 seconds (Sampling)
Chain 3:                0.33 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: 0.189 seconds (Warm-up)
Chain 4:                0.131 seconds (Sampling)
Chain 4:                0.32 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.
```

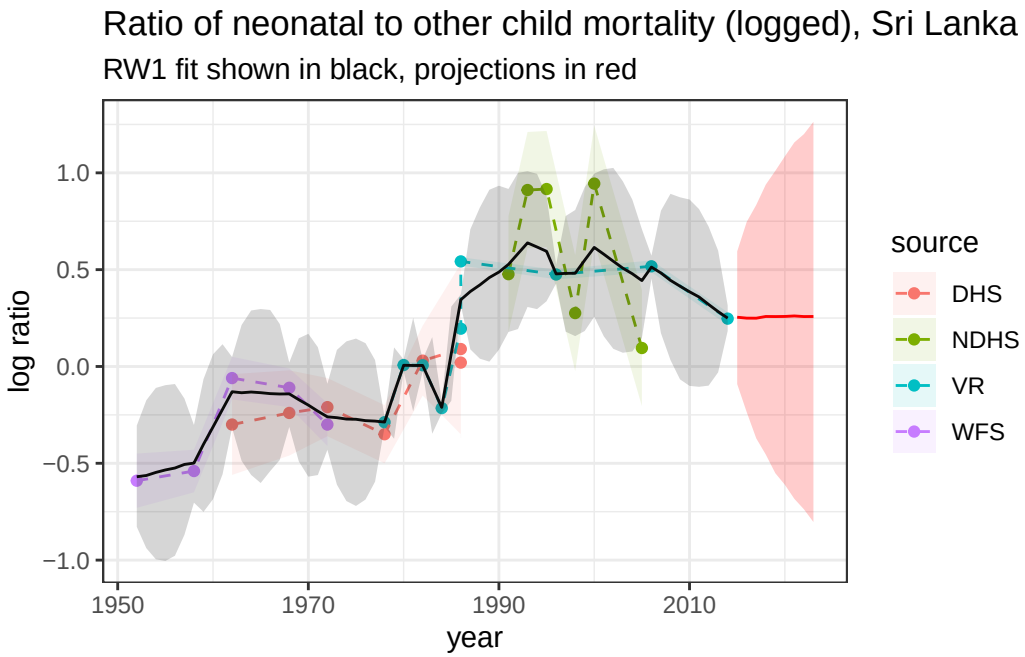
	mean	se_mean	sd	2.5%	25%	50%	75%	97.5%	n_eff	Rhat
mu[1]	-0.57	0.00	0.13	-0.83	-0.66	-0.57	-0.48	-0.31	4090	1
mu[2]	-0.56	0.00	0.19	-0.94	-0.69	-0.56	-0.43	-0.17	3234	1
mu[3]	-0.55	0.00	0.22	-1.00	-0.69	-0.55	-0.40	-0.11	2918	1
mu[4]	-0.54	0.00	0.23	-1.00	-0.69	-0.53	-0.39	-0.10	2875	1
mu[5]	-0.52	0.00	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 Thu Mar 23 09:25:18 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).
```

```r
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)
```

```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 = 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 2.7e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.27 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)
```

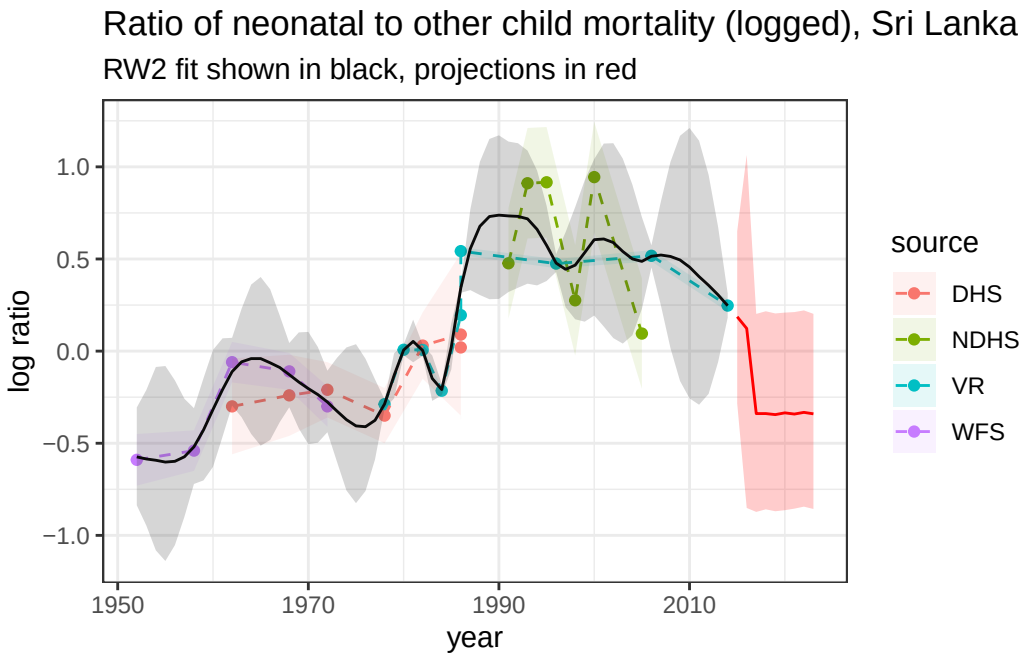
```
Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
Chain 1:
Chain 1:  Elapsed Time: 0.588 seconds (Warm-up)
Chain 1:                0.6 seconds (Sampling)
Chain 1:                1.188 seconds (Total)
Chain 1:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
Chain 2:
Chain 2: Gradient evaluation took 9e-06 seconds
Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.09 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: 0.582 seconds (Warm-up)
Chain 2:                0.535 seconds (Sampling)
Chain 2:                1.117 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 1e-05 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.1 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: 0.63 seconds (Warm-up)
Chain 3:                0.606 seconds (Sampling)
Chain 3:                1.236 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 8e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.08 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: 0.587 seconds (Warm-up)
Chain 4:                0.578 seconds (Sampling)
```

```
Chain 4:                1.165 seconds (Total)
Chain 4:
```

```r
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)
```

```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 = 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")
```

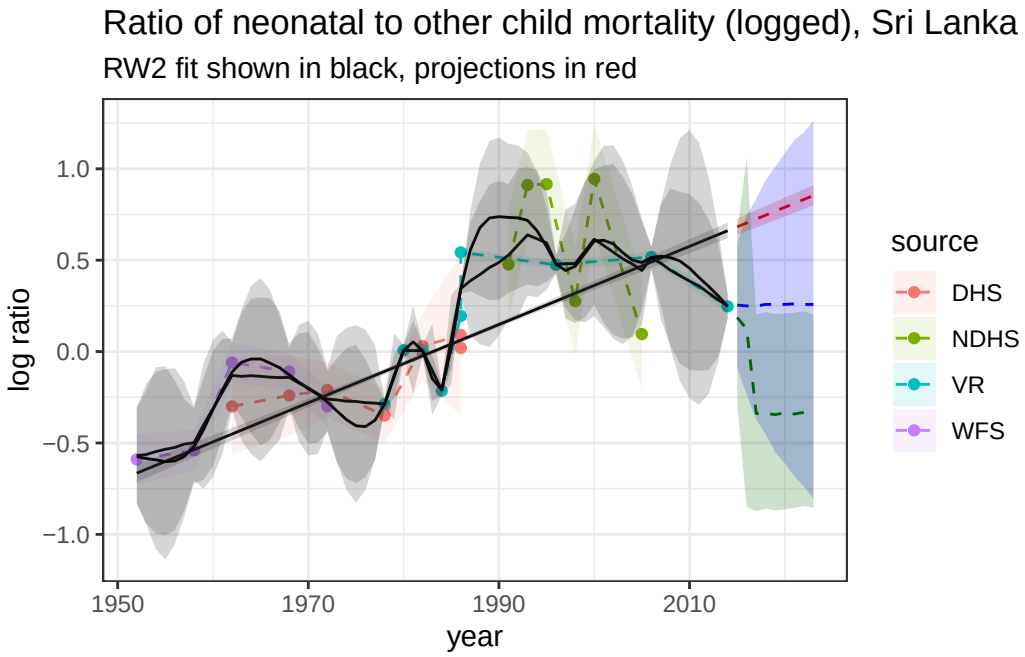


Question 4

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.

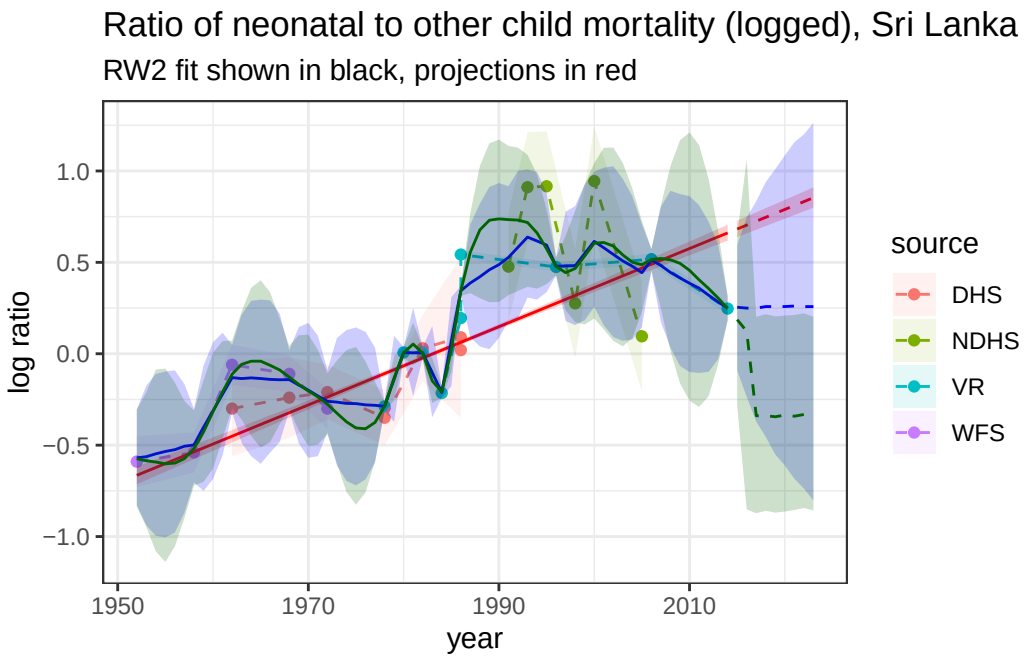
```
ggplot(lka, aes(year, logit_ratio)) +
  geom_point(aes( color = source)) +
  geom_line(aes( color = source), lty = 2) +
  geom_ribbon(aes(ymin = logit_ratio - se,
                  ymax = logit_ratio + se,
                  fill =  source), alpha = 0.1) +
  theme_bw()+
  # Linear Model
  geom_line(data = res1a, aes(year, .value)) +
  geom_ribbon(data = res1a, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
  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)) +
  geom_ribbon(data = res2a, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
```

```
  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)) +
  geom_ribbon(data = res3a, aes(y = .value, ymin = .lower, ymax = .upper), alpha = 0.2)+
  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")
```




```
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.

```r
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 1.1e-05 seconds
Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.11 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: 1.7 seconds (Warm-up)
```

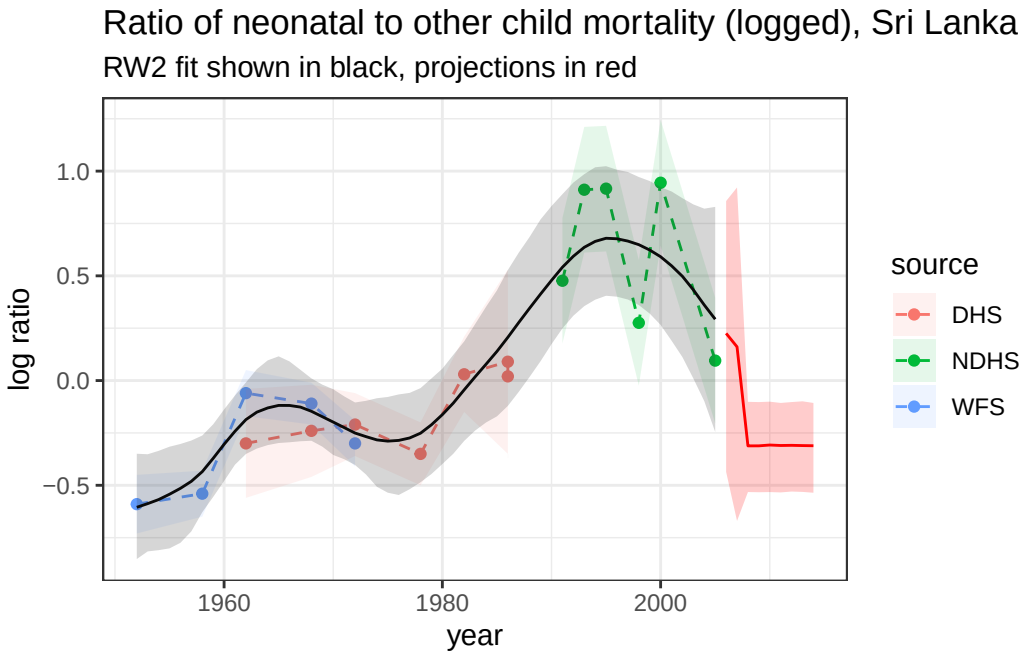
```
Chain 1:                3.18 seconds (Sampling)
Chain 1:                4.88 seconds (Total)
Chain 1:

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: 1.932 seconds (Warm-up)
Chain 2:                1.692 seconds (Sampling)
Chain 2:                3.624 seconds (Total)
Chain 2:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
Chain 3:
Chain 3: Gradient evaluation took 8e-06 seconds
Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.08 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: 1.784 seconds (Warm-up)
Chain 3:                0.759 seconds (Sampling)
Chain 3:                2.543 seconds (Total)
Chain 3:

SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
Chain 4:
Chain 4: Gradient evaluation took 8e-06 seconds
Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.08 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: 2.266 seconds (Warm-up)
Chain 4:                2.866 seconds (Sampling)
Chain 4:                5.132 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)
```

```
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")
```



We see that when there is less data the trend loses much of its characteristic linear property.

Now it seems as though child mortality might be decreasing, after it increased. This means that our prediction learns this, and the resulting output child mortality is smaller than it was in previous years. This is a good thing, but does not follow the general trend we have seen, so it is a little more unlike the data.

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. 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.