My title*

My subtitle if needed

Ahnaf Alam

March 16, 2024

First sentence. Second sentence. Third sentence. Fourth sentence.

1 Introduction

You can and should cross-reference sections and sub-sections. We use R Core Team (2023) and Wickham et al. (2019).

The remainder of this paper is structured as follows. Section 2….

2 Data

Some of our data is of penguins (**?@fig-bills**), from Horst, Hill, and Gorman (2020).

Table 1: Description of cleaned data

Variable	Description
Date	Date of data collected
Durable goods	Real expenditure in durable goods
Non-durable goods	Real expenditure in non-durable goods
Food	Real food expenditure
Disposable income	Real disposable income
Healthcare	Real expenditure in healthcare
Services	Real expenditure in services

```
data |>
  ggplot(aes(x = date)) +
```

*Code and data are available at: LINK.

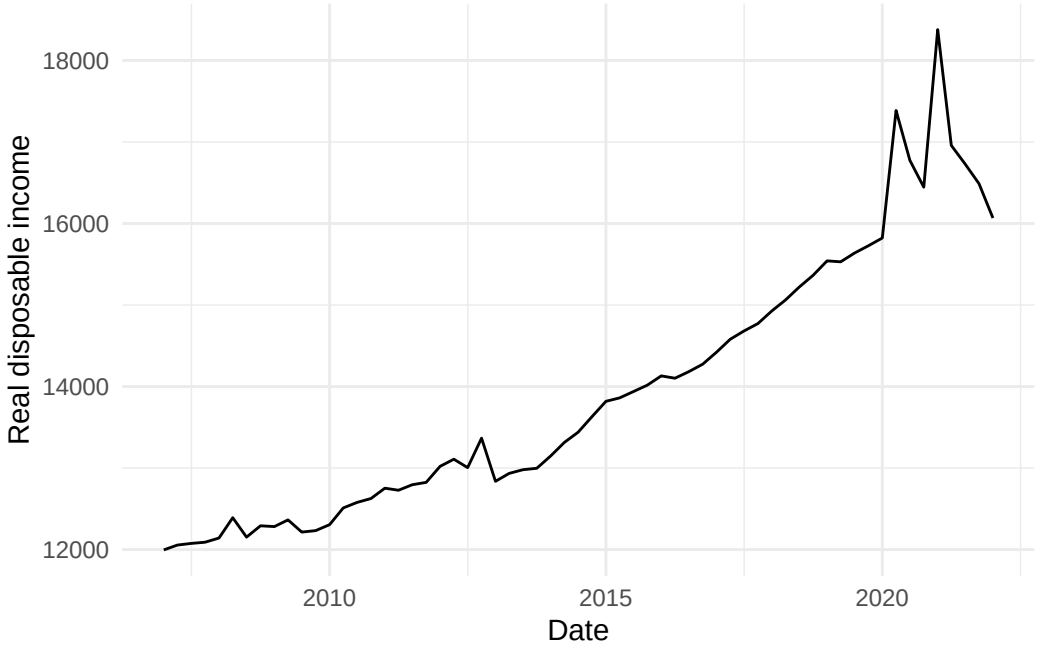


Figure 1: Relationship between wing length and width

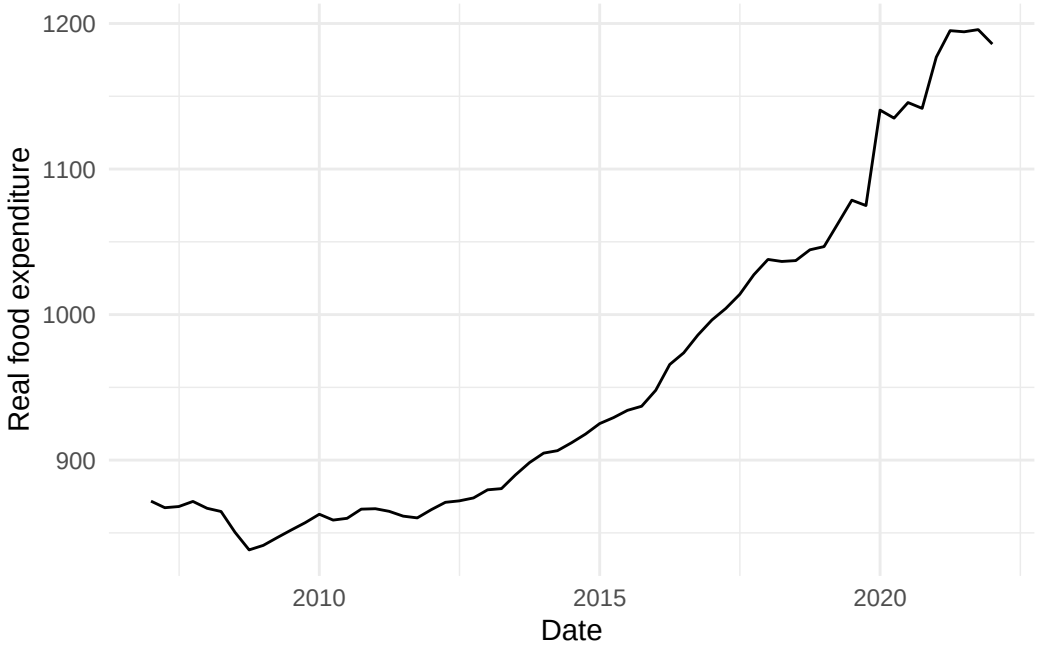
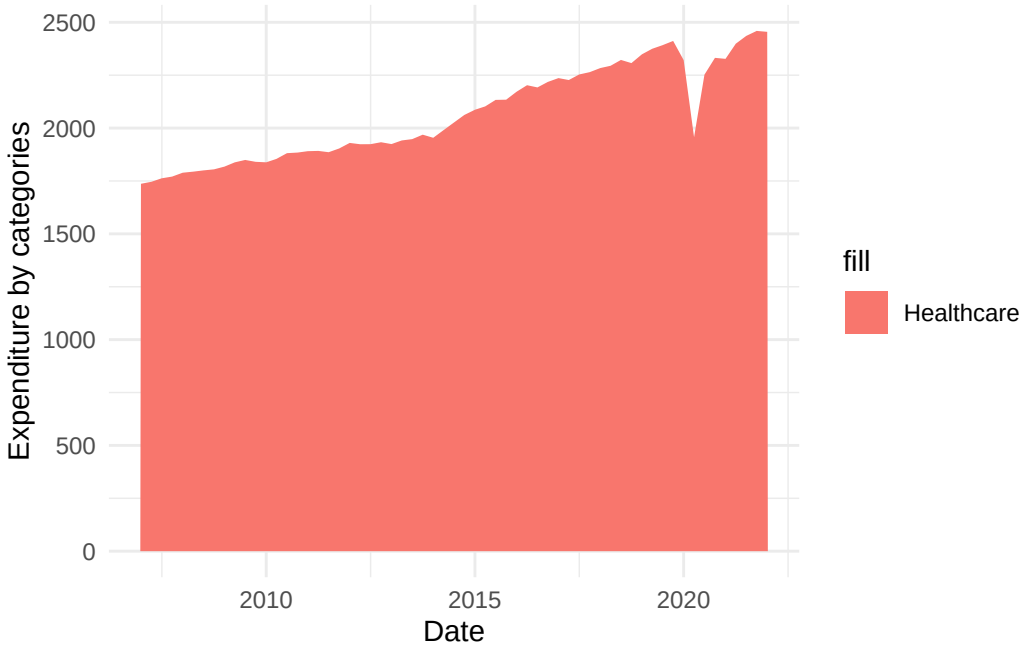


Figure 2: Relationship between wing length and width

```r
  geom_area(aes(y = healthcare_expenditure, fill = "Healthcare")) +
  #geom_area(aes(y = nondurable_expenditure, fill = "Non-durable goods")) +
  #geom_area(aes(y = durable_expenditure, fill = "Durable goods")) +
  #geom_area(aes(y = services_expenditure, fill = "Services")) +
  labs(
    x = "Date",
    y = "Expenditure by categories"
  ) +
  theme_minimal()
```



	date	variable	value
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2	2007-04-01	durable_expenditure	980.100
3	2007-07-01	durable_expenditure	992.100
4	2007-10-01	durable_expenditure	999.500
5	2008-01-01	durable_expenditure	967.200
6	2008-04-01	durable_expenditure	960.300
7	2008-07-01	durable_expenditure	927.900
8	2008-10-01	durable_expenditure	859.600
9	2009-01-01	durable_expenditure	861.100
10	2009-04-01	durable_expenditure	854.900
11	2009-07-01	durable_expenditure	896.400

12	2009-10-01	durable_expenditure	875.300
13	2010-01-01	durable_expenditure	886.000
14	2010-04-01	durable_expenditure	913.900
15	2010-07-01	durable_expenditure	928.200
16	2010-10-01	durable_expenditure	954.200
17	2011-01-01	durable_expenditure	962.600
18	2011-04-01	durable_expenditure	955.800
19	2011-07-01	durable_expenditure	964.200
20	2011-10-01	durable_expenditure	987.400
21	2012-01-01	durable_expenditure	1011.500
22	2012-04-01	durable_expenditure	1013.400
23	2012-07-01	durable_expenditure	1026.600
24	2012-10-01	durable_expenditure	1049.800
25	2013-01-01	durable_expenditure	1076.200
26	2013-04-01	durable_expenditure	1081.500
27	2013-07-01	durable_expenditure	1091.300
28	2013-10-01	durable_expenditure	1102.500
29	2014-01-01	durable_expenditure	1121.000
30	2014-04-01	durable_expenditure	1162.800
31	2014-07-01	durable_expenditure	1183.000
32	2014-10-01	durable_expenditure	1205.900
33	2015-01-01	durable_expenditure	1228.900
34	2015-04-01	durable_expenditure	1253.700
35	2015-07-01	durable_expenditure	1270.100
36	2015-10-01	durable_expenditure	1278.300
37	2016-01-01	durable_expenditure	1295.300
38	2016-04-01	durable_expenditure	1306.300
39	2016-07-01	durable_expenditure	1339.700
40	2016-10-01	durable_expenditure	1360.800
41	2017-01-01	durable_expenditure	1371.700
42	2017-04-01	durable_expenditure	1389.200
43	2017-07-01	durable_expenditure	1424.900
44	2017-10-01	durable_expenditure	1477.800
45	2018-01-01	durable_expenditure	1496.900
46	2018-04-01	durable_expenditure	1505.600
47	2018-07-01	durable_expenditure	1516.400
48	2018-10-01	durable_expenditure	1518.900
49	2019-01-01	durable_expenditure	1507.000
50	2019-04-01	durable_expenditure	1545.200
51	2019-07-01	durable_expenditure	1580.500
52	2019-10-01	durable_expenditure	1602.900
53	2020-01-01	durable_expenditure	1531.700
54	2020-04-01	durable_expenditure	1530.900

55	2020-07-01	durable_expenditure	1822.100
56	2020-10-01	durable_expenditure	1847.500
57	2021-01-01	durable_expenditure	1966.700
58	2021-04-01	durable_expenditure	2033.700
59	2021-07-01	durable_expenditure	1904.300
60	2021-10-01	durable_expenditure	1954.900
61	2022-01-01	durable_expenditure	1962.300
62	2007-01-01	nondurable_expenditure	2435.000
63	2007-04-01	nondurable_expenditure	2429.900
64	2007-07-01	nondurable_expenditure	2437.500
65	2007-10-01	nondurable_expenditure	2435.500
66	2008-01-01	nondurable_expenditure	2416.600
67	2008-04-01	nondurable_expenditure	2420.400
68	2008-07-01	nondurable_expenditure	2385.100
69	2008-10-01	nondurable_expenditure	2362.300
70	2009-01-01	nondurable_expenditure	2361.400
71	2009-04-01	nondurable_expenditure	2347.300
72	2009-07-01	nondurable_expenditure	2354.700
73	2009-10-01	nondurable_expenditure	2362.300
74	2010-01-01	nondurable_expenditure	2374.800
75	2010-04-01	nondurable_expenditure	2387.900
76	2010-07-01	nondurable_expenditure	2396.800
77	2010-10-01	nondurable_expenditure	2414.600
78	2011-01-01	nondurable_expenditure	2422.700
79	2011-04-01	nondurable_expenditure	2417.500
80	2011-07-01	nondurable_expenditure	2409.300
81	2011-10-01	nondurable_expenditure	2408.700
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83	2012-04-01	nondurable_expenditure	2423.600
84	2012-07-01	nondurable_expenditure	2424.800
85	2012-10-01	nondurable_expenditure	2424.800
86	2013-01-01	nondurable_expenditure	2461.500
87	2013-04-01	nondurable_expenditure	2463.700
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89	2013-10-01	nondurable_expenditure	2506.700
90	2014-01-01	nondurable_expenditure	2514.700
91	2014-04-01	nondurable_expenditure	2540.300
92	2014-07-01	nondurable_expenditure	2561.800
93	2014-10-01	nondurable_expenditure	2592.400
94	2015-01-01	nondurable_expenditure	2618.200
95	2015-04-01	nondurable_expenditure	2634.000
96	2015-07-01	nondurable_expenditure	2661.600
97	2015-10-01	nondurable_expenditure	2671.700

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98  2016-01-01 nondurable_expenditure  2696.600
99  2016-04-01 nondurable_expenditure  2720.400
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102 2017-01-01 nondurable_expenditure  2759.500
103 2017-04-01 nondurable_expenditure  2785.800
104 2017-07-01 nondurable_expenditure  2801.800
105 2017-10-01 nondurable_expenditure  2838.100
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107 2018-04-01 nondurable_expenditure  2860.700
108 2018-07-01 nondurable_expenditure  2870.000
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110 2019-01-01 nondurable_expenditure  2910.900
111 2019-04-01 nondurable_expenditure  2946.100
112 2019-07-01 nondurable_expenditure  2975.200
113 2019-10-01 nondurable_expenditure  2974.800
114 2020-01-01 nondurable_expenditure  3019.000
115 2020-04-01 nondurable_expenditure  2919.800
116 2020-07-01 nondurable_expenditure  3122.800
117 2020-10-01 nondurable_expenditure  3136.600
118 2021-01-01 nondurable_expenditure  3212.900
119 2021-04-01 nondurable_expenditure  3325.900
120 2021-07-01 nondurable_expenditure  3335.000
121 2021-10-01 nondurable_expenditure  3356.300
122 2022-01-01 nondurable_expenditure  3333.400
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124 2007-04-01       food_expenditure   867.300
125 2007-07-01       food_expenditure   868.100
126 2007-10-01       food_expenditure   871.600
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128 2008-04-01       food_expenditure   864.700
129 2008-07-01       food_expenditure   850.400
130 2008-10-01       food_expenditure   838.300
131 2009-01-01       food_expenditure   841.400
132 2009-04-01       food_expenditure   846.700
133 2009-07-01       food_expenditure   851.900
134 2009-10-01       food_expenditure   857.000
135 2010-01-01       food_expenditure   862.800
136 2010-04-01       food_expenditure   858.800
137 2010-07-01       food_expenditure   860.000
138 2010-10-01       food_expenditure   866.300
139 2011-01-01       food_expenditure   866.600
140 2011-04-01       food_expenditure   864.800
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142	2011-10-01	food_expenditure	860.300
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144	2012-04-01	food_expenditure	871.000
145	2012-07-01	food_expenditure	872.000
146	2012-10-01	food_expenditure	874.000
147	2013-01-01	food_expenditure	879.600
148	2013-04-01	food_expenditure	880.400
149	2013-07-01	food_expenditure	889.800
150	2013-10-01	food_expenditure	898.300
151	2014-01-01	food_expenditure	904.800
152	2014-04-01	food_expenditure	906.500
153	2014-07-01	food_expenditure	911.900
154	2014-10-01	food_expenditure	917.900
155	2015-01-01	food_expenditure	925.100
156	2015-04-01	food_expenditure	929.200
157	2015-07-01	food_expenditure	934.200
158	2015-10-01	food_expenditure	937.000
159	2016-01-01	food_expenditure	948.000
160	2016-04-01	food_expenditure	965.700
161	2016-07-01	food_expenditure	973.700
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163	2017-01-01	food_expenditure	996.300
164	2017-04-01	food_expenditure	1004.200
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168	2018-04-01	food_expenditure	1036.500
169	2018-07-01	food_expenditure	1037.100
170	2018-10-01	food_expenditure	1044.500
171	2019-01-01	food_expenditure	1046.700
172	2019-04-01	food_expenditure	1062.500
173	2019-07-01	food_expenditure	1078.600
174	2019-10-01	food_expenditure	1074.900
175	2020-01-01	food_expenditure	1140.500
176	2020-04-01	food_expenditure	1135.000
177	2020-07-01	food_expenditure	1145.700
178	2020-10-01	food_expenditure	1141.700
179	2021-01-01	food_expenditure	1176.900
180	2021-04-01	food_expenditure	1195.100
181	2021-07-01	food_expenditure	1194.300
182	2021-10-01	food_expenditure	1195.800
183	2022-01-01	food_expenditure	1185.900

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186 2007-07-01     income_expenditure 12075.600
187 2007-10-01     income_expenditure 12090.300
188 2008-01-01     income_expenditure 12141.600
189 2008-04-01     income_expenditure 12391.200
190 2008-07-01     income_expenditure 12152.800
191 2008-10-01     income_expenditure 12291.700
192 2009-01-01     income_expenditure 12282.000
193 2009-04-01     income_expenditure 12364.400
194 2009-07-01     income_expenditure 12214.700
195 2009-10-01     income_expenditure 12232.600
196 2010-01-01     income_expenditure 12306.000
197 2010-04-01     income_expenditure 12510.600
198 2010-07-01     income_expenditure 12578.500
199 2010-10-01     income_expenditure 12626.100
200 2011-01-01     income_expenditure 12753.100
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202 2011-07-01     income_expenditure 12795.700
203 2011-10-01     income_expenditure 12824.400
204 2012-01-01     income_expenditure 13021.200
205 2012-04-01     income_expenditure 13108.700
206 2012-07-01     income_expenditure 13004.800
207 2012-10-01     income_expenditure 13366.800
208 2013-01-01     income_expenditure 12837.200
209 2013-04-01     income_expenditure 12934.400
210 2013-07-01     income_expenditure 12979.600
211 2013-10-01     income_expenditure 12997.500
212 2014-01-01     income_expenditure 13149.100
213 2014-04-01     income_expenditure 13314.500
214 2014-07-01     income_expenditure 13439.700
215 2014-10-01     income_expenditure 13631.400
216 2015-01-01     income_expenditure 13819.000
217 2015-04-01     income_expenditure 13860.600
218 2015-07-01     income_expenditure 13937.900
219 2015-10-01     income_expenditure 14016.800
220 2016-01-01     income_expenditure 14130.600
221 2016-04-01     income_expenditure 14102.200
222 2016-07-01     income_expenditure 14182.000
223 2016-10-01     income_expenditure 14274.200
224 2017-01-01     income_expenditure 14422.300
225 2017-04-01     income_expenditure 14579.600
226 2017-07-01     income_expenditure 14681.500
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228 2018-01-01     income_expenditure 14927.500
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231 2018-10-01     income_expenditure 15365.300
232 2019-01-01     income_expenditure 15541.400
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239 2020-10-01     income_expenditure 16445.400
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241 2021-04-01     income_expenditure 16957.300
242 2021-07-01     income_expenditure 16730.700
243 2021-10-01     income_expenditure 16488.600
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259 2010-07-01 healthcare_expenditure  1881.324
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262 2011-04-01 healthcare_expenditure  1892.152
263 2011-07-01 healthcare_expenditure  1885.927
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265 2012-01-01 healthcare_expenditure  1929.808
266 2012-04-01 healthcare_expenditure  1923.667
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268 2012-10-01 healthcare_expenditure  1933.068
269 2013-01-01 healthcare_expenditure  1924.413
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273 2014-01-01 healthcare_expenditure  1954.171
274 2014-04-01 healthcare_expenditure  1990.080
275 2014-07-01 healthcare_expenditure  2026.130
276 2014-10-01 healthcare_expenditure  2062.272
277 2015-01-01 healthcare_expenditure  2086.633
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288 2017-10-01 healthcare_expenditure  2264.434
289 2018-01-01 healthcare_expenditure  2283.591
290 2018-04-01 healthcare_expenditure  2294.406
291 2018-07-01 healthcare_expenditure  2322.059
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305 2022-01-01 healthcare_expenditure  2454.946
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309 2007-10-01   services_expenditure 26088.000
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312 2008-07-01   services_expenditure 26186.000
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317 2009-10-01   services_expenditure 25795.000
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320 2010-07-01   services_expenditure 26123.000
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331 2013-04-01   services_expenditure 26277.000
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334 2014-01-01   services_expenditure 26434.000
335 2014-04-01   services_expenditure 26522.000
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343 2016-04-01   services_expenditure 27381.000
344 2016-07-01   services_expenditure 27468.000
345 2016-10-01   services_expenditure 27540.000
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347 2017-04-01   services_expenditure 27715.000
348 2017-07-01   services_expenditure 27781.000
349 2017-10-01   services_expenditure 27908.000
350 2018-01-01   services_expenditure 28051.000
351 2018-04-01   services_expenditure 28204.000
352 2018-07-01   services_expenditure 28290.000
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354 2019-01-01   services_expenditure 28301.000
355 2019-04-01   services_expenditure 28385.000
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357 2019-10-01   services_expenditure 28741.000
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359 2020-04-01   services_expenditure 24841.000
360 2020-07-01   services_expenditure 26769.000
361 2020-10-01   services_expenditure 27200.000
362 2021-01-01   services_expenditure 27544.000
363 2021-04-01   services_expenditure 28388.000
364 2021-07-01   services_expenditure 28996.000
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366 2022-01-01   services_expenditure 29229.000
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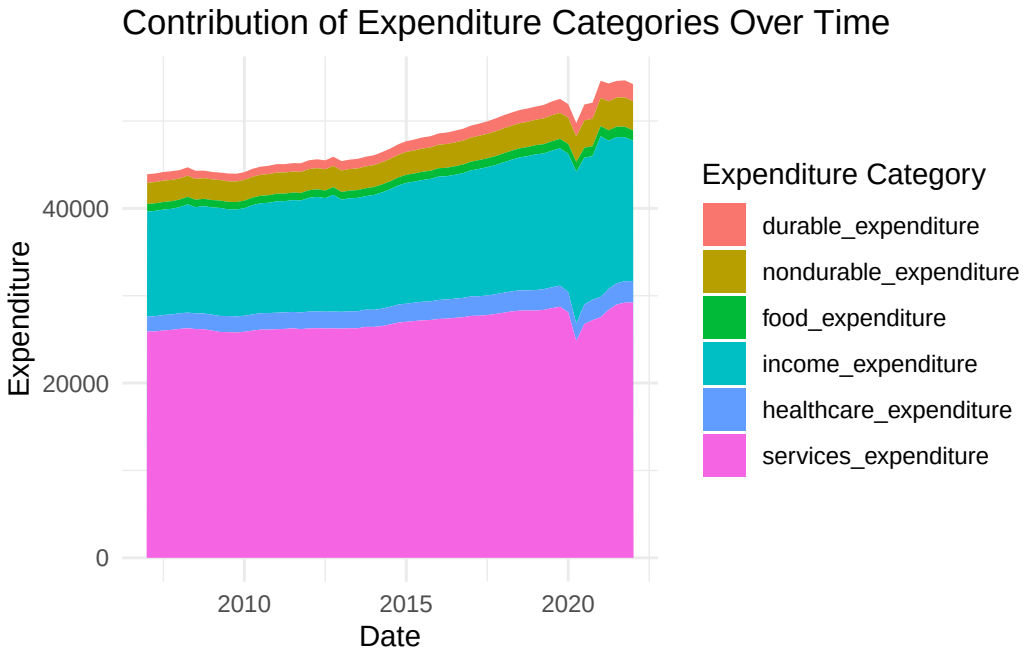


Figure 3: Relationship between wing length and w

Talk more about it.

And also planes (Figure 4). (You can change the height and width, but don't worry about doing that until you have finished every other aspect of the paper - Quarto will try to make it look nice and the defaults usually work well once you have enough text.)

Talk way more about it.

Table 2: Cleaned data showing real expenditure by different categories

Date	Durable goods	Non-durable goods	Food	Disposable income	Healthcare	Services
2007-01-01	969.90	2435.00	871.80	11995.90	1736.72	25900.00
2007-04-01	980.10	2429.90	867.30	12055.30	1745.91	25913.00
2007-07-01	992.10	2437.50	868.10	12075.60	1762.55	26024.00
2007-10-01	999.50	2435.50	871.60	12090.30	1770.73	26088.00
2008-01-01	967.20	2416.60	866.90	12141.60	1788.97	26202.00
2008-04-01	960.30	2420.40	864.70	12391.20	1793.99	26273.00
2008-07-01	927.90	2385.10	850.40	12152.80	1800.01	26186.00
2008-10-01	859.60	2362.30	838.30	12291.70	1804.94	26167.00
2009-01-01	861.10	2361.40	841.40	12282.00	1817.91	26012.00
2009-04-01	854.90	2347.30	846.70	12364.40	1838.01	25848.00
2009-07-01	896.40	2354.70	851.90	12214.70	1849.31	25830.00
2009-10-01	875.30	2362.30	857.00	12232.60	1840.44	25795.00

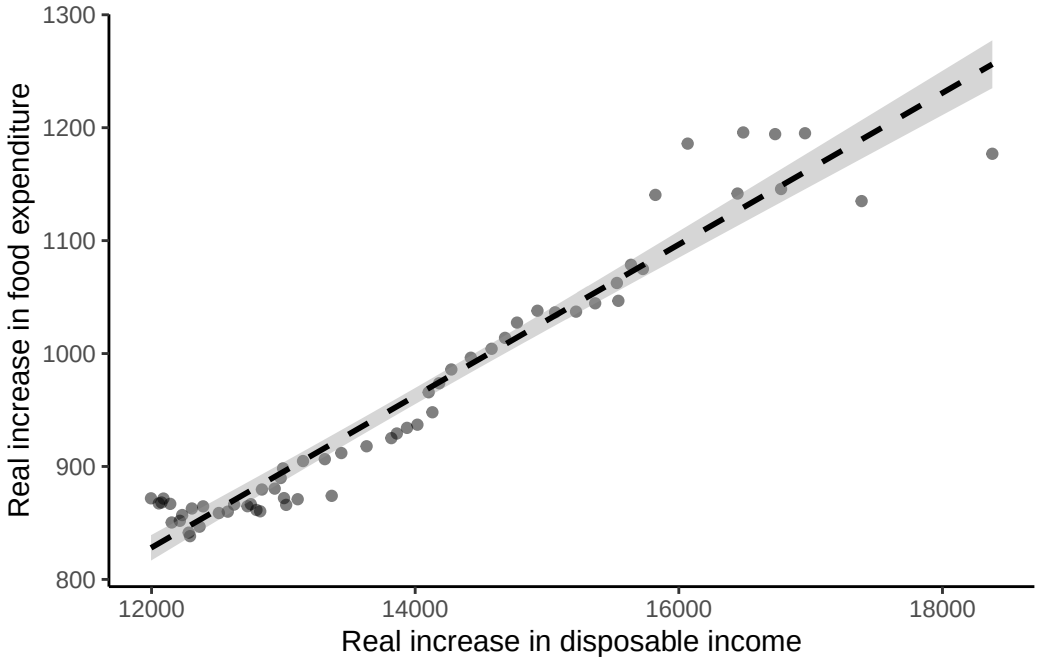


Figure 4: Relationship between wing length and width

	First Model	Second Model
(Intercept)	24.07	−97.50
	(30.88)	(114.73)
income_expenditure	0.07	0.02
	(0.00)	(0.00)
durable_expenditure		−0.15
		(0.04)
nondurable_expenditure		0.47
		(0.04)
healthcare_expenditure		0.00
		(0.04)
services_expenditure		−0.01
		(0.01)
Num.Obs.	61	61
R2	0.936	0.992
R2 Adj.	0.933	0.990
Log.Lik.	−289.419	−224.943
ELPD	−292.9	−233.0
ELPD s.e.	8.0	8.0
LOOIC	585.7	466.0
LOOIC s.e.	16.0	16.0
WAIC	585.6	464.3
RMSE	27.49	10.36

3 Model

The goal of our modelling strategy is twofold. Firstly,…

Here we briefly describe the Bayesian analysis model used to investigate… Background details and diagnostics are included in Appendix B.

3.1 Model set-up

Define y_i as the number of seconds that the plane remained aloft. Then β_i is the wing width and γ_i is the wing length, both measured in millimeters.

$$y_i|\mu_i, \sigma \sim \text{Normal}(\mu_i, \sigma) \tag{1}$$
$$\mu_i = \alpha + \beta_i + \gamma_i \tag{2}$$
$$\alpha \sim \text{Normal}(0, 2.5) \tag{3}$$
$$\beta \sim \text{Normal}(0, 2.5) \tag{4}$$
$$\gamma \sim \text{Normal}(0, 2.5) \tag{5}$$
$$\sigma \sim \text{Exponential}(1) \tag{6}$$

We run the model in R (R Core Team 2023) using the `rstanarm` package of Goodrich et al. (2022). We use the default priors from `rstanarm`.

3.1.1 Model justification

We expect a positive relationship between the size of the wings and time spent aloft. In particular...

We can use maths by including latex between dollar signs, for instance θ.

4 Results

Our results are summarized in **?@tbl-modelresults**.

5 Discussion

5.1 First discussion point

If my paper were 10 pages, then should be be at least 2.5 pages. The discussion is a chance to show off what you know and what you learnt from all this.

5.2 Second discussion point

5.3 Third discussion point

5.4 Weaknesses and next steps

Weaknesses and next steps should also be included.

Appendix

We are at the back end of covid-19 pandemic yet risks of another widespread epidemic is still rather underestimated. At the beginning of this pandemic, public health officials were rather caught off-guard with the emergence and virulence of this disease. As such, public were relayed lots of mixed messages regarding what they can do to mitigate the risk of infection and this confusion only added to public panic. Measures like Spain banning smoking in public were, or mandatory gloves Russia and Ukraine were implemented, which may sound absurd right now, although at the time seemed reasonable. However, public health experts soon realized effectiveness of masks in slowing transmission rate. A meta-analysis, consisting of 6 studies from 4 different countries show that masks significantly reduce transmission risks (OR = 0.38, 95% CI: 0.21-0.69, I2 = 54.1%) , and among health care workers, masks reduce transmission by as much as 70%.

A Additional data details

B Model details

B.1 Posterior predictive check

In **?@fig-ppcheckandposteriorvsprior-1** we implement a posterior predictive check. This shows...

In **?@fig-ppcheckandposteriorvsprior-2** we compare the posterior with the prior. This shows...

Examining how the model fits, and is affected by, the data

Figure 5: **?(caption)**

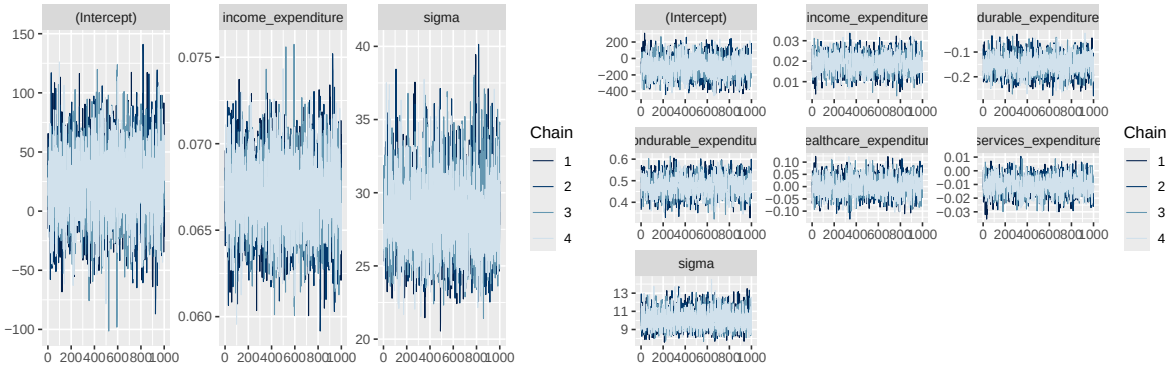
Examining how the model fits, and is affected by, the data

Figure 6: **?(caption)**

B.2 Diagnostics

Figure 7a is a trace plot. It shows... This suggests...

Figure 7b is a Rhat plot. It shows... This suggests...



(a) Trace plot

(b) Rhat plot

Figure 7: Checking the convergence of the MCMC algorithm

References

Goodrich, Ben, Jonah Gabry, Imad Ali, and Sam Brilleman. 2022. "Rstanarm: Bayesian Applied Regression Modeling via Stan." https://mc-stan.org/rstanarm/.

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