

**Chapter 7: Comparing proportions and distributions**

7.1 a)  $H_0$ : The 2019 distribution is equal to the historical distribution  
 $H_1$ : The 2019 distribution is not equal to the historical distribution

7.1 b) Expected number = Historical %  $\times$  Observed number

	Historical	Observed ( $O$ )	Expected ( $E$ )	$O - E$	$\frac{(O-E)^2}{E}$
Spring	4.87 (30%)	2.90	25.2	11.8	5.525
Summer	3.04 (40%)	4.50	33.6	-6.6	1.296
Fall	1.65 (15%)	4.94	12.6	-0.6	0.029
Winter	2.88 (15%)	3.28	12.6	-4.6	1.679
Total	2.31 (100%)	4.73	84		8.530

7.1 c) Since every season has an expected value above 5 you can do a chi-square test.

7.1 d)  $X^2 = 8.530$

7.1 e) The calculated chi-square value of 8.530 is higher than the critical chi-square value of 7.8.  $H_0$  is rejected. The 2019 distribution is significantly different from the historical distribution. There is a 5% risk of a type-I error.

7.1 f) You rejected the null hypothesis  $H_0$  with 95% confidence, and so the p-value must be lower than 0.05.

7.1 g)  $X^2 = 8.530$

```
Observed <- c(37, 27, 12, 8)
Historical <- c(0.3, 0.4, 0.15, 0.15)
Expected <- c(25.2, 33.6, 12.6, 12.6)

chi <- sum((Observed - Expected)^2 / Expected) # 8.530
```

7.1 h) Yes.

```
qchisq(p = 0.95, df = 3) # 7.185
```

- 7.1 i) R returns the same chi-squared as calculated, so the answer was correct. It also shows a p-value of below 0.05, as expected.

```
# chi-square test: x = observations p = model distribution
# rescale makes sure the model distribution adds up to 100%
chisq.test(x = Observed, p = Historical, rescale.p = TRUE)

# Chi-squared value: 8.5298
# p-value: 0.0362
```

- 7.1 j) The expected values are 25.2, 33.6, 12.6, and 12.6. R shows the same expected values.

```
chisq <- chisq.test(x = Observed, p = Historical)
chisq$expected # Extract expected values with $expected
# 25.2 33.6 12.6 12.6
```

- 7.2 a) The `sales` data frame contains 3 columns: `month`, `historical` and `newstore`. It contains the 'Historical' and 'New Store' distribution of sales over the months.

```
# These are the values for the sales data set
sales <- data.frame(month = seq(from = 1, to = 12, by = 1),
                    historical = c(5.1, 5.1, 6.7, 10, 11.4, 10,
                                   6.7, 5.1, 6.7, 10, 11.7, 11.7),
                    newstore = c(5.6, 6.2, 9.4, 8.6, 6.8, 4.8,
                                 5.6, 4.8, 8.8, 12.6, 13.1, 13.7))

summary(sales)
```

- 7.2 b) The chi-square test requires every cell in the expected distribution to have a value of at least 5 and it requires the total of both groups to be equal. Since the historical distribution contains more than 5 in every cell and both observed and expected values add up to the same number (100) we can use this for a chi-squared test.
- 7.2 c)  $H_0$ : The new distribution is equal to the historical distribution  
 $H_1$ : The new distribution is not equal to the historical distribution

- 7.2 d) The p-value of 0.6963 is higher than the critical p-value of 0.10.  $H_0$  is not rejected. The new store distribution is not significantly different from the historical distribution. There is a risk a type-II error.

```
chisq.test(x = sales$newstore, p = sales$historical, rescale.p = TRUE)
# p-value: 0.6963
```

- 7.3 a) The best estimate of the population proportion  $\pi$  is the sample proportion  $p$ .

$$\pi_1 = \frac{k}{n} = \frac{8}{71} = 0.113$$

$$\pi_2 = \frac{k}{n} = \frac{16}{111} = 0.144$$

- 7.3 b) Confidence interval sample 1:

$$p \pm z_\alpha \times \sqrt{\frac{p(1-p)}{n}} = 0.113 \pm 1.960 \times \sqrt{\frac{0.113 \times (1-0.113)}{71}} = [0.039; 0.187]$$

Confidence interval sample 2:

$$p \pm z_\alpha \times \sqrt{\frac{p(1-p)}{n}} = 0.144 \pm 1.960 \times \sqrt{\frac{0.144 \times (1-0.144)}{111}} = [0.078; 0.210]$$

- 7.3 c)  $H_0: \pi_2 \leq \pi_1$   $H_1: \pi_2 > \pi_1$

Where  $\pi_2$  and  $\pi_1$  are the success proportions for the evening and afternoon calls respectively.

- 7.3 d) Combined success probability:

$$p^* = \frac{k_1 + k_2}{n_1 + n_2} = \frac{8 + 16}{71 + 111} = 0.132$$

- 7.3 e) Combined standard error:

$$s_p = \sqrt{p^*(1-p^*)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)} = \sqrt{0.132(1-0.132)\left(\frac{1}{71} + \frac{1}{111}\right)} = 0.0514$$

- 7.3 f) z-score:  $\frac{p_1 - p_2}{s_p} = \frac{0.144 - 0.113}{0.0514} = 0.612$

Note that  $p_1$  and  $p_2$  were switched because in the hypotheses  $\pi_1$  and  $\pi_2$  were also switched.

- 7.3 g) The calculated z-score of 0.612 is lower than the critical z-value of 1.645.  $H_0$  is not rejected. The evening success rate is not shown to be significantly higher than the afternoon success rate. There is a risk of a type-II error.

- 7.3 h) The code creates a vector of successes `k` and a vector of sample sizes `n`. The proportion test then tests the equality. It shows the proportions you calculated earlier, and a p-value of 0.6984 which supports your conclusion if you do not reject  $H_0$ .

```
n <- c(71, 111)
k <- c(8, 16)
prop.test(x = k, n = n)
# p-value: 0.6984
```

Note that R actually returns a chi-squared value. Because it actually does a chi-square test it can in fact be used to test more than two proportions at the same time.