

Chapter 9

Hypothesis Testing

Learning Objectives

1. Learn how to formulate and test hypotheses about a population mean and/or a population proportion.
2. Understand the types of errors possible when conducting a hypothesis test.
3. Be able to determine the probability of making various errors in hypothesis tests.
4. Know how to compute and interpret P -values.
5. Be able to use critical values to draw hypothesis testing conclusions.
6. Be able to determine the size of a simple random sample necessary to keep the probability of hypothesis testing errors within acceptable limits.
7. Know the definition of the following terms:

null hypothesis	two-tailed test
alternative hypothesis	P -value
Type I error	level of significance
Type II error	critical value
one-tail test	

Solutions:

1. a. $H_0: \mu \leq 600$ Manager's claim.
 $H_a: \mu > 600$
 - b. We are not able to conclude that the manager's claim is wrong.
 - c. The manager's claim can be rejected. We can conclude that $\mu > 600$.
2. a. $H_0: \mu \leq 14$
 $H_a: \mu > 14$ Research hypothesis
 - b. There is no statistical evidence that the new bonus plan increases sales volume.
 - c. The research hypothesis that $\mu > 14$ is supported. We can conclude that the new bonus plan increases the mean sales volume.
3. a. $H_0: \mu = 32$ Specified filling weight
 $H_a: \mu \neq 32$ Overfilling or underfilling exists
 - b. There is no evidence that the production line is not operating properly. Allow the production process to continue.
 - c. Conclude $\mu \neq 32$ and that overfilling or underfilling exists. Shut down and adjust the production line.
4. a. $H_0: \mu \geq 220$
 $H_a: \mu < 220$ Research hypothesis to see if mean cost is less than \$220.
 - b. We are unable to conclude that the new method reduces costs.
 - c. Conclude $\mu < 220$. Consider implementing the new method based on the conclusion that it lowers the mean cost per hour.
5. a. The Type I error is rejecting H_0 when it is true. This error occurs if the researcher concludes that young men in Germany spend more than 56.2 minutes per day watching prime-time TV when the national average for Germans is not greater than 56.2 minutes.
 - b. The Type II error is accepting H_0 when it is false. This error occurs if the researcher concludes that the national average for German young men is ≤ 56.2 minutes when in fact it is greater than 56.2 minutes.
6. a. $H_0: \mu \leq 1$ The label claim or assumption.
 $H_a: \mu > 1$
 - b. Claiming $\mu > 1$ when it is not. This is the error of rejecting the product's claim when the claim is true.

- c. Concluding $\mu \leq 1$ when it is not. In this case, we miss the fact that the product is not meeting its label specification.

7. a. $H_0: \mu \leq 8000$

$H_a: \mu > 8000$ Research hypothesis to see if the plan increases average sales.

- b. Claiming $\mu > 8000$ when the plan does not increase sales. A mistake could be implementing the plan when it does not help.

- c. Concluding $\mu \leq 8000$ when the plan really would increase sales. This could lead to not implementing a plan that would increase sales.

8. a. $H_0: \mu \geq 220$

$H_a: \mu < 220$

- b. Claiming $\mu < 220$ when the new method does not lower costs. A mistake could be implementing the method when it does not help.

- c. Concluding $\mu \geq 220$ when the method really would lower costs. This could lead to not implementing a method that would lower costs.

9. a.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{19.4 - 20}{2 / \sqrt{50}} = -2.12$$

b. Area = .4830

$p\text{-value} = .5000 - .4830 = .0170$

- c. $p\text{-value} \leq .05$, reject H_0

- d. Reject H_0 if $z \leq -1.645$

$-2.12 \leq -1.645$, reject H_0

10. a.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{26.4 - 25}{6 / \sqrt{40}} = 1.48$$

b. Area = .4306

$p\text{-value} = .5000 - .4306 = .0694$

- c. $p\text{-value} > .01$, do not reject H_0

- d. Reject H_0 if $z \geq 2.33$

$1.48 < 2.33$, do not reject H_0

11. a. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{14.15 - 15}{3 / \sqrt{50}} = -2.00$

b. Area = .4772

$p\text{-value} = 2(.5000 - .4772) = .0456$

c. $p\text{-value} \leq .05$, reject H_0

d. Reject H_0 if $z \leq -1.96$ or $z \geq 1.96$

$-2.00 \leq -1.96$, reject H_0

12. a. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{78.5 - 80}{12 / \sqrt{100}} = -1.25$

$p\text{-value} = .5000 - .3944 = .1056$

$p\text{-value} > .01$, do not reject H_0

b. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{77 - 80}{12 / \sqrt{100}} = -2.50$

$p\text{-value} = .5000 - .4938 = .0062$

$p\text{-value} \leq .01$, reject H_0

c. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{75.5 - 80}{12 / \sqrt{100}} = -3.75$

$p\text{-value} \approx 0$

$p\text{-value} \leq .01$, reject H_0

d. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{81 - 80}{12 / \sqrt{100}} = .83$

Area to left of $z = .83$

$p\text{-value} = .5000 + .2967 = .7967$

$p\text{-value} > .01$, do not reject H_0

13. Reject H_0 if $z \geq 1.645$

a. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{52.5 - 50}{8 / \sqrt{60}} = 2.42$

$2.42 \geq 1.645$, reject H_0

b.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{51 - 50}{8 / \sqrt{60}} = .97$$

.97 < 1.645, do not reject H_0

c.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{51.8 - 50}{8 / \sqrt{60}} = 1.74$$

1.74 ≥ 1.645, reject H_0

14. a.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{23 - 22}{10 / \sqrt{75}} = .87$$

$$p\text{-value} = 2(.5000 - .3078) = .3844$$

$p\text{-value} > .01$, do not reject H_0

b.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{25.1 - 22}{10 / \sqrt{75}} = 2.68$$

$$p\text{-value} = 2(.5000 - .4963) = .0074$$

$p\text{-value} \leq .01$, reject H_0

c.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{20 - 22}{10 / \sqrt{75}} = -1.73$$

$$p\text{-value} = 2(.5000 - .4582) = .0836$$

$p\text{-value} > .01$, do not reject H_0

15. a. $H_0: \mu \geq 1056$

$H_a: \mu < 1056$

b.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{910 - 1056}{1600 / \sqrt{400}} = -1.83$$

$$p\text{-value} = .5000 - .4664 = .0336$$

c. $p\text{-value} \leq .05$, reject H_0 . Conclude the mean refund of “last minute” filers is less than \$1056.

d. Reject H_0 if $z \leq -1.645$

$$-1.83 \leq -1.645$$
, reject H_0

16. a. $H_0: \mu \leq 895$

$H_a: \mu > 895$

$$b. \quad z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{915 - 895}{225 / \sqrt{180}} = 1.19$$

$$\text{Area} = .3830$$

$$p\text{-value} = .5000 - .3830 = .1170$$

- c. Do not reject H_0 . We cannot conclude the rental rates have increased.
- d. Recommend withholding judgment and collecting more data on apartment rental rates before drawing a final conclusion.

$$17. a. \quad H_0: \mu = 39.2$$

$$H_a: \mu \neq 39.2$$

$$b. \quad z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{38.5 - 39.2}{4.8 / \sqrt{112}} = -1.54$$

$$p\text{-value} = 2(.5000 - .4382) = .1236$$

- c. $p\text{-value} > .05$, do not reject H_0 . We cannot conclude that the mean length of a work week has changed.
- d. Reject H_0 if $z \leq -1.96$ or $z \geq 1.96$

$$z = -1.54; \text{ cannot reject } H_0$$

$$18. a. \quad H_0: \mu = 4.1$$

$$H_a: \mu \neq 4.1$$

$$b. \quad z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{3.4 - 4.1}{2 / \sqrt{40}} = -2.21$$

$$p\text{-value} = 2(.5000 - .4864) = .0272$$

- c. $p\text{-value} = .0272 < .05$

Reject H_0 and conclude that the return for Mid-Cap Growth Funds differs significantly from that for U.S. Diversified funds.

$$19. \quad H_0: \mu \leq 14.32$$

$$H_a: \mu > 14.32$$

$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{14.68 - 14.32}{1.45 / \sqrt{75}} = 2.15$$

$$\text{Area} = .4842$$

$$p\text{-value} = .5000 - .4842 = .0158$$

P -value $\leq .05$, reject H_0 . Conclude that there has been an increase in the mean hourly wage of production workers.

20. a. $H_0: \mu \geq 181,900$

$H_a: \mu < 181,900$

b.
$$z = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}} = \frac{166,400 - 181,900}{33,500 / \sqrt{40}} = -2.93$$

c. P -value = .5000 - .4983 = .0017

d. P -value $\leq .01$; reject H_0 . Conclude mean selling price in South is less than the national mean selling price.

21. a. $H_0: \mu \leq 15$

$H_a: \mu > 15$

b.
$$z = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}} = \frac{17 - 15}{4 / \sqrt{35}} = 2.96$$

c. P -value = .5000 - .4985 = .0015

d. P -value $\leq .01$; reject H_0 ; the premium rate should be charged.

22. a. $H_0: \mu = 8$

$H_a: \mu \neq 8$

b.
$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{8.4 - 8}{3.2 / \sqrt{120}} = 1.37$$

P -value = 2(.5000 - .4147) = .1706

c. Do not reject H_0 . Cannot conclude that the population mean waiting time differs from 8 minutes.

d. $\bar{x} \pm z_{.025}(\sigma / \sqrt{n})$

$8.4 \pm 1.96(3.2 / \sqrt{120})$

$8.4 \pm .57 \quad (7.83 \text{ to } 8.97)$

Yes; $\mu = 8$ is in the interval. Do not reject H_0 .

23. a.
$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{14 - 12}{4.32 / \sqrt{25}} = 2.31$$

- b. Degrees of freedom = $n - 1 = 24$
- Using t_{table} , p -value is between .01 and .025.
- Actual p -value = .0147
- c. p -value $\leq .05$, reject H_0 .
- d. With $df = 24$, $t_{.05} = 1.711$
- Reject H_0 if $t \geq 1.711$
- $2.31 > 1.711$, reject H_0 .
24. a. $t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{17 - 18}{4.5 / \sqrt{48}} = -1.54$
- b. Degrees of freedom = $n - 1 = 47$
- Area in lower tail is between .05 and .10
- Using t_{table} , p -value (two-tail) is between .10 and .20
- Actual p -value = .1304
- c. p -value $> .05$, do not reject H_0 .
- d. With $df = 47$, $t_{.025} = 2.012$
- Reject H_0 if $t \leq -2.012$ or $t \geq 2.012$
- $t = -1.54$; do not reject H_0
25. a. $t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{44 - 45}{5.2 / \sqrt{36}} = -1.15$
- Degrees of freedom = $n - 1 = 35$
- Using t_{table} , p -value is between .10 and .20
- Actual p -value = .1282
- p -value $> .01$, do not reject H_0
- b. $t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{43 - 45}{4.6 / \sqrt{36}} = -2.61$
- Using t_{table} , p -value is between .005 and .01
- Actual p -value = .0066

P -value $\leq .01$, reject H_0

$$c. \quad t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{46 - 45}{5 / \sqrt{36}} = 1.20$$

Using t table, area in upper tail is between .10 and .20

P -value (lower tail) is between .80 and .90

Actual P -value = .8809

P -value $> .01$, do not reject H_0

$$26. a. \quad t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{103 - 100}{11.5 / \sqrt{65}} = 2.10$$

Degrees of freedom = $n - 1 = 64$

Using t table, area in tail is between .01 and .025

P -value (two tail) is between .02 and .05

Actual P -value = .0394

P -value $\leq .05$, reject H_0

$$b. \quad t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{96.5 - 100}{11 / \sqrt{65}} = -2.57$$

Using t table, area in tail is between .005 and .01

P -value (two tail) is between .01 and .02

Actual P -value = .0127

P -value $\leq .05$, reject H_0

$$c. \quad t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{102 - 100}{10.5 / \sqrt{65}} = 1.54$$

Using t table, area in tail is between .05 and .10

P -value (two tail) is between .10 and .20

Actual P -value = .1295

P -value $> .05$, do not reject H_0

$$27. a. \quad H_0: \mu \geq 238$$

$$H_a: \mu < 238$$

$$b. \quad t = \frac{x - \mu_0}{s / \sqrt{n}} = \frac{231 - 238}{80 / \sqrt{100}} = -.88$$

Degrees of freedom = $n - 1 = 99$

Using t -table, p -value is between .10 and .20

Actual p -value = .1918

c. p -value > .05; do not reject H_0 . Cannot conclude mean weekly benefit in Virginia is less than the national mean.

$$d. \quad df = 99 \quad t_{.05} = -1.66$$

Reject H_0 if $t \leq -1.66$

$-.88 > -1.66$; do not reject H_0

$$28. a. \quad H_0: \mu \leq 3530$$

$$H_a: \mu > 3530$$

$$b. \quad t = \frac{x - \mu_0}{s / \sqrt{n}} = \frac{3740 - 3530}{810 / \sqrt{92}} = 2.49$$

Degrees of freedom = $n - 1 = 91$

Using t -table, p -value is between .005 and .01

Actual p -value = .0074

c. p -value $\leq .01$; reject H_0 . The mean attendance per game has increased. Anticipate a new all-time high season attendance during the 2002 season.

$$29. a. \quad H_0: \mu = 5600$$

$$H_a: \mu \neq 5600$$

$$b. \quad t = \frac{x - \mu_0}{s / \sqrt{n}} = \frac{5835 - 5600}{520 / \sqrt{25}} = 2.26$$

Degrees of freedom = $n - 1 = 24$

Using t -table, area in tail is between .01 and .025

Actual p -value = .0332

c. p -value $\leq .05$; reject H_0 . The mean diamond price in New York City differs.

$$d. \quad df = 24 \quad t_{.025} = 2.064$$

Reject H_0 if $t < -2.064$ or $t > 2.064$

$2.26 > 2.064$; reject H_0

30. a. $H_0: \mu = 600$

$H_a: \mu \neq 600$

b.
$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{612 - 600}{65 / \sqrt{40}} = 1.17$$

$df = n - 1 = 39$

Using t -table, area in tail is between .10 and .20

P -value is between .20 and .40

Actual P -value = .2501

c. With $\alpha = .10$ or less, we cannot reject H_0 . We are unable to conclude there has been a change in the mean CNN viewing audience.

d. The sample mean of 612 thousand viewers is encouraging but not conclusive for the sample of 40 days. Recommend additional viewer audience data. A larger sample should help clarify the situation for CNN.

31. $H_0: \mu \leq 47.50$

$H_a: \mu > 47.50$

$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{51 - 47.50}{12 / \sqrt{64}} = 2.33$$

Degrees of freedom = $n - 1 = 63$

Using t -table, P -value is between .01 and .025

Actual P -value = .0114

Reject H_0 ; Atlanta customers are paying a higher mean water bill.

32. a. $H_0: \mu = 10,192$

$H_a: \mu \neq 10,192$

b.
$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} = \frac{9750 - 10,192}{1400 / \sqrt{50}} = -2.23$$

Degrees of freedom = $n - 1 = 49$

Using t -table, area in tail is between .01 and .025

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