

## Chapter 5 Project: Broiler Chicken Production

Name \_\_\_\_\_ Name \_\_\_\_\_

### 1. Background information

The graph and data that form the basis of this project were taken from a very useful web site sponsored by the National Agricultural Statistics Service (NASS) of the United States Department of Agriculture (USDA). Broiler chicken production is given on a yearly basis, from 1960 to 2002 (see diagram and table). The units of broiler chicken production are in billions of pounds ( $10^9$  pounds). Sounds like a lot, but if 250 million U.S. citizens ate 0.5 pounds of chicken a week (one drumstick and one thigh), that's 6 billion pounds! Some of the broilers are exported, and others turn up in strange places such as pet food.

Inspect the graph of the 1960-2002 data. Do the data look linear or exponential? Do you expect a good exponential fit to the data, an OK exponential fit to the data, or a poor exponential fit to the data?

### 2. Prep and graph the data

a) To download the project data into StatCrunch electronically, go to the Chapter 5 Project at the EnviroMath website ([www.enviromath.com](http://www.enviromath.com)) and click on the “click here” link. You will be transferred to the StatCrunch website, where you must log in (new users must register). After logging in, StatCrunch will automatically load the project data into the first three columns and re-label the column headers (see instruction 2 below on re-labeling).

To enter the data manually, go to the StatCrunch website ([www.statcrunch.com](http://www.statcrunch.com)) and log in (new users must register).

1. In StatCrunch you will see columns labeled var1, var2, var3, etc., and rows marked 1, 2, 3, and so on. Enter the years after 1960 numbers (0, 1, 2, etc.) into column **var1**. Enter the broiler production data (in billions of pounds) into column **var2** (5.0, 5.7, etc.). Enter the population data (in millions of people) into column **var3** (180.7, 183.7, etc.). When finished, make sure that there are 43 entries in each column, and scan for possible typing mistakes.
2. Re-label the column headers. Click on var1, then backspace to erase. Then type in **year**. Similarly, re-label var2 as **production** and var3 as **population**.
3. Select **Data > Save data** and enter a file name such as “Chicken.” Check the box “overwrite existing file” (if active) and set the delimiter to “space.” Click on **Save**. (*You should repeat this step often, to save any updated work!*)

b) Graph the (years, billions of pounds) data. Click on **Graphics > Scatter Plot**. From the pull down menus, select **year** for the independent variable  $x$  and **production** for the dependent variable  $y$ . Follow the **Next** buttons to modify the graph layout or just skip to **Create Graph!**

### 3. Approximating the data – the straightedge method

Calculate the logarithms of the broiler production data by first clicking on **Data > Transform Data**. At the top of the new window, type in **log10 (production)** and then press **Transform** at the bottom of the window. Note that “log” in StatCrunch is actually the natural logarithm “ln.” Inspect the log10 (production) column to make sure that the numbers are reasonable (check year 11, for example). Record the numbers in the table, using 2 decimal places of precision.

a) Plot the (years, log(production)) values on the graph paper provided. Choose scales so that you make use of as much of the graph paper as is convenient. Label appropriately.

b) Using a straightedge, draw a best-fitting line through the transformed data. Then find the equation of the line in the form  $\log(y) = mx + b$ . Show work below. *Note: retain all decimal places while doing your computations.*

c) Using the slope and y-intercept of the line through the transformed data, find the exponential function through the original data. Show work below. *Round the y-intercept to 3 decimal places and the multiplier to 4 decimal places.*

### 4. Approximating the data – least squares regression

StatCrunch does not have a least squares *exponential* regression, however the *linear* regression through the transformed data provides the identical information, after a small amount of algebra. To find the linear regression equation through the transformed data, select **STAT > Regression > Simple Linear**, and set the X-Variable to years and the Y-Variable to log (production). Skip directly to **Calculate**.

a) Write out the best fitting linear regression for the transformed data:

$$\log_{10}(\text{production}) = \underline{\hspace{10em}}$$

Using the slope and  $y$ -intercept through the transformed data, find the best fitting exponential regression through the original data (as in the straightedge method). Show work. Round the  $y$ -intercept to 3 decimal places and the multiplier to 4 decimal places.

- b) What is the value of the correlation coefficient  $r$ ?  $r =$  \_\_\_\_\_  
How well does an exponential model fit the data? Explain.

### **5. Comparing the 2 Methods**

- a) Summarize the results of the two methods in the table below. Round the  $y$ -intercepts to 3 decimal places and the multipliers to 4 decimal places.

	straightedge	least squares regression
$y$ -intercept ( $y_0$ )		
multiplier (M)		

- b) Are there units of measure associated with the  $y$ -intercept in each equation? Explain.
- c) Are there units of measure associated with the multiplier in each equation? Explain.
- d) Do the multipliers have the correct value for the data ( $M > 1$  or  $M < 1$ )? Explain.

e) Do the y-intercepts ( $y_0$ ) have the right value? Explain.

f) By what percentage (approximately) has broiler production increased each year from 1960 to 2002?

### **6. Evaluating the least squares regression model**

a) Let's evaluate more closely the best-fitting regression equation. Does this regression equation give reasonable values for broiler production? Answer this question by calculating the percentage that the equation value is above or below the actual broiler production values given by the USDA. Fill in the table as directed:

	<b>actual value</b>	<b>equation value</b>	<b>% above or % below</b>
1970			
1990			

b) Does the regression equation give reasonable values for the years 1970 and 1990? Explain.

c) Scan the production data in the table. Approximately how many years did it take for production to double from 5 billion pounds/year to 10? 10 to 20? 20 to 40? Using these numbers, what is the (average) doubling time?

	<b>doubling time in years</b>
5 - 10	
10 - 20	
20 - 40	

average doubling time \_\_\_\_\_

d) Now calculate the doubling time by working directly with the exponential regression equation. Show work. How does this doubling time compare to the average doubling time you estimated above?

### **7. Cause of Exponential Growth of Chickens: Part A**

a) Why has broiler production increased exponentially in the United States in the last 40 years? Think of at least two different reasons that would explain an exponential increase in the production of broiler chickens. These answers are hypotheses, potential (but unproven) ideas that may explain the explosive increase in brawwkkkk!

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Don't modify these two hypotheses; keep what you've written. One potential explanation for the exponential growth of chicken production is an *exponential increase in the number of U.S. residents eating chicken*. We can test this hypothesis by looking at U.S. population. Start by adding the transformed population data to your StatCrunch table. Under **Data > Transform data**, enter **log10 (population)** at the top of the window and press **Transform** at the bottom of the window. Check your results in the table.

b) Find the best fit linear regression equation through the transformed data. Under **Stat > Regression > Simple Linear**, choose years and log10 (population) as the two variables. What is the least squares linear regression?

Using the slope and y-intercept through the transformed data, find the best fitting exponential regression through the original data. Show work. *Round the y-intercept to 3 decimal places and the multiplier to 4 decimal places.*

c) What is the correlation coefficient  $r$  for this best-fitting exponential regression?

d) Is an exponential function a good fit to the data, a mediocre fit to the data, or a poor fit to the data? In other words, how exponential is U.S. population growth; how well does an exponential function model U.S. population?

e) In conclusion, is the "exponential population" hypothesis supported or negated by your quantitative analysis? Explain briefly.

### **8. Cause of Exponential Growth of Chickens: Part B**

The spokesperson for the Beef Board says: "you have made a critical assumption in your analysis, and therefore your analysis is wrong." The PR person has a good point. In order to explain exponential chicken production by exponential growth of the U.S. population, you must show that the two are linked, connected. For example, the number of automobiles in the U.S. has also grown exponentially over this 42-year period, but SUVs are not responsible for an increase in drumsticks. So what is the link, the connection, the *cause and effect* between people and chicken?

a) This is a simple but important question. There is a three word answer...what is it?

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b) Let's examine this connection by calculating the per capita production of broiler chicken for each year in units of "pounds per person." Note that production data have units of billions of pounds, and population data have units of millions of people. To get the correct units in our StatCrunch table, go to **Data > Transform data** and enter the following:  $(\text{production} * 10^9) / (\text{population} * 10^6)$ . Then press **Transform**. Inspect the results to see if they are reasonable. Record values in the table provided, using 1 decimal place of precision.

c) What was the per capita production of broiler chicken in 1960? In 2002? Has the per capita production gone down, stayed the same, or gone up with time?

d) Can the exponential growth of the U.S. population explain *all* the change in broiler chicken production? If not, *what else* happened in this time period? Explain.

	<b>var1</b>	<b>var2</b>	<b>var3</b>	<b>var4</b>	<b>var5</b>
<b>year</b>	<b>year</b>	<b>production (<math>\times 10^9</math> lbs.)</b>	<b>U.S. population (<math>\times 10^6</math>)</b>	<b>log(production)</b>	<b>per capita production (pounds/person)</b>
1960	0	5.0	180.7		
1961	1	5.7	183.7		
1962	2	5.7	186.5		
1963	3	8.5	189.2		
1964	4	6.5	191.9		
1965	5	7.0	194.3		
1966	6	7.7	196.6		
1967	7	8.2	198.7		
1968	8	8.2	200.7		
1969	9	8.8	202.7		
1970	10	10.0	205.1		
1971	11	10.0	207.7		
1972	12	10.9	209.9		
1973	13	10.9	211.9		
1974	14	10.9	213.9		
1975	15	11.0	216.0		
1976	16	12.3	218.0		
1977	17	12.6	220.2		
1978	18	13.4	222.6		
1979	19	15.1	225.1		
1980	20	15.6	227.7		
1981	21	16.5	230.0		
1982	22	16.5	232.2		
1983	23	16.9	234.3		
1984	24	17.7	236.3		
1985	25	18.5	238.5		
1986	26	19.5	240.7		
1987	27	20.9	242.8		
1988	28	22.1	245.0		
1989	29	23.6	247.3		
1990	30	25.3	250.1		
1991	31	27.0	253.5		
1992	32	29.0	256.9		
1993	33	30.6	260.3		
1994	34	32.5	263.4		
1995	35	34.2	266.6		
1996	36	36.5	269.7		
1997	37	37.5	272.9		
1998	38	38.6	276.1		
1999	39	40.8	279.3		
2000	40	41.6	282.4		
2001	41	42.4	285.5		
2002	42	44.1	288.6		

