Ag & Applied Economics 374 — Brad Barham and John Morrow
Fall 2008 — TA: Andres Moya

The Growth and Development of Nations

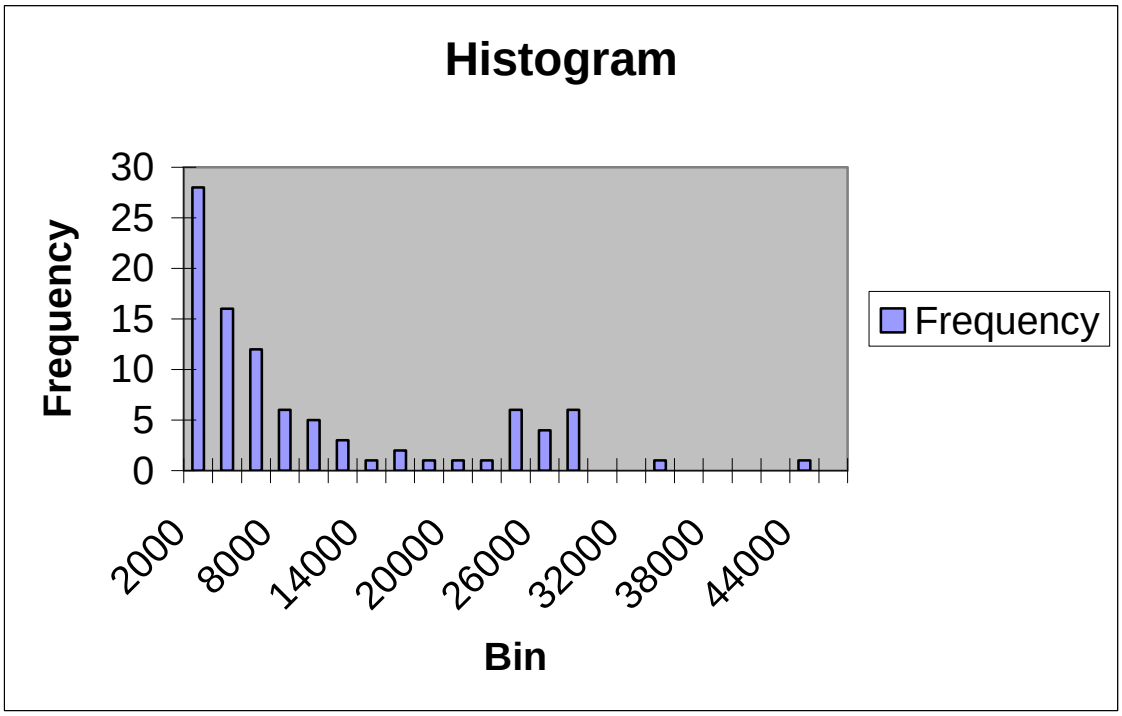
Problem Set 2: Economic Growth and Unconditional Convergence

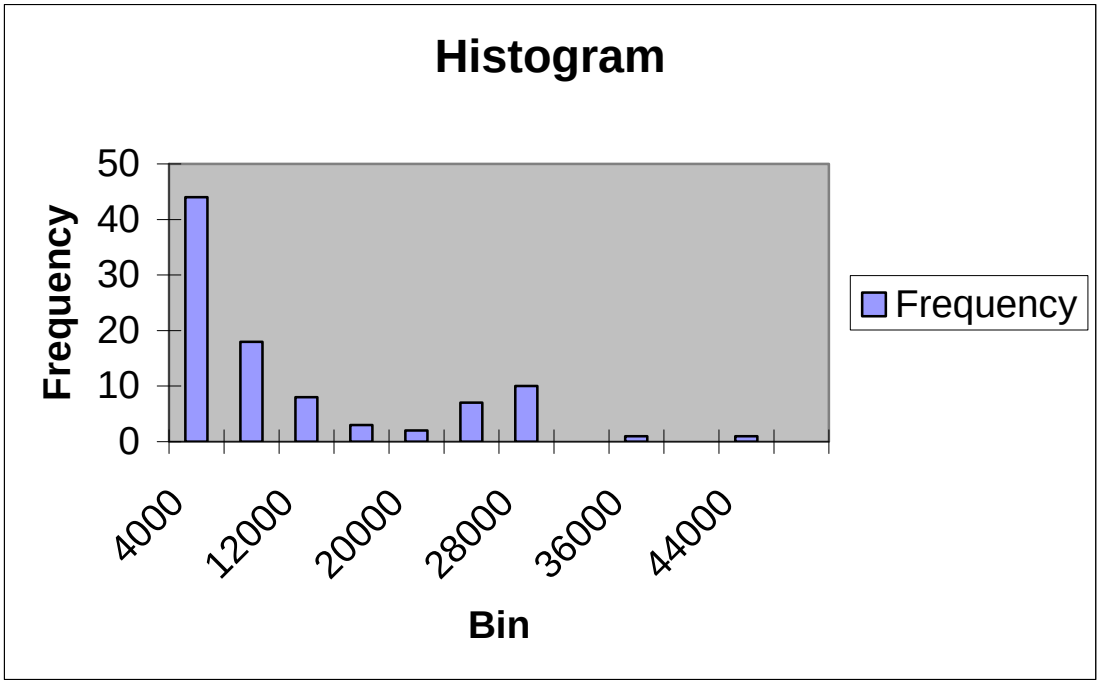
ANSWER KEY

1. The file **PSET2-06.XLS** contains a worksheet called **2000** that contains 2000 per-capita GDP levels for all countries for which such data is available in both 2000 and 1960. GDP levels are measured in purchasing power parity adjusted to 1996 $US. This data is the real stuff and is widely used by economists. It comes from the Penn World Tables, maintained by Professors Summers and Heston at the University of Pennsylvania (http://pwt.econ.upenn.edu).

   a. Using the **2000** data, create a histogram that shows the distribution of 2000 per-capita GDP levels for the nations of the world.

ANSWER: I have pasted below two examples of histograms you could have made to answer this question depending on the bin range that you have selected.





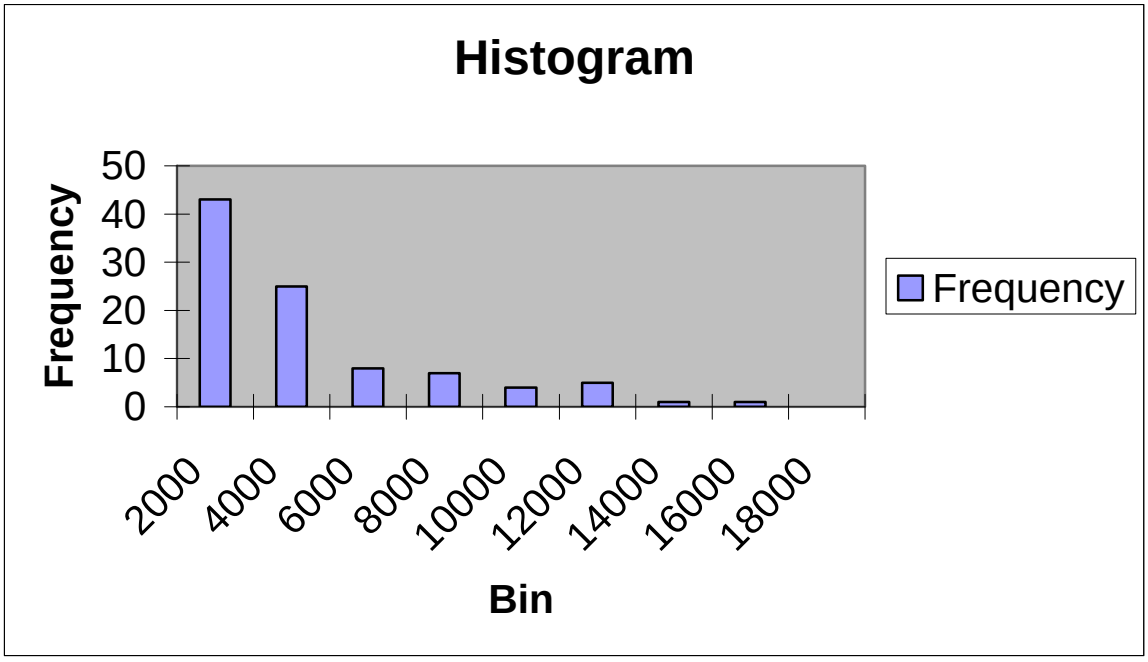
b. Briefly describe the resulting distribution in terms of its shape, center (central tendency) and spread.

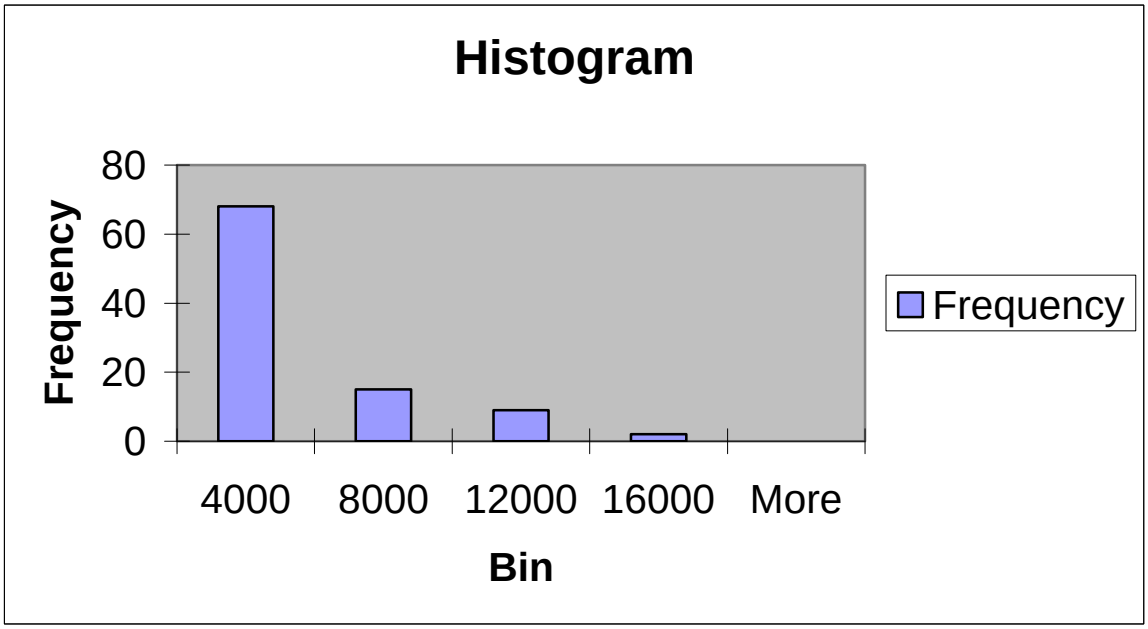
ANSWER: The histogram looks skewed right (this means there is a long tail on the right hand side but none on the left hand side). There are many very poor countries and then a few extremely rich ones. There seem to be very few countries in between. The distribution seems to be bimodal (this means that there are two major 'lumps' of countries). We see a big mass of countries in the under $4000 range and a big mass in the upper $20,000 range and then a few countries somewhere in between. It is a bit hard to tell by eye-balling the data what the average is, probably somewhere around $15,000, in between the very poor and the very rich. Around half of the countries have incomes below $4000 per person per year (so that is the median). Around a quarter of the countries have incomes between $4000 and $14000 and a quarter of the countries have incomes above $14000.

2. The file **PSET2-06.XLS** also contains 1960 per-capita GDP levels in the worksheet **1960**.

   a. Create a histogram for the distribution of 1960 per-capita GDP. To make comparisons between 2000 and 1960 easier, you may want to use the same data range classes for the 1960 histogram that you used for the 2000 histogram.

ANSWER: I have pasted two examples below of histograms using the same data range classes as before. This time I have cut them off at $16000 since there are no countries richer than that, whereas in 2000 the richest country approached $44000.





b. Describe the shape, center and spread of the 1960 distribution. Do the 1960 and 2000 distributions appear to be very different? If so, please describe the differences and relate them to the discussion about convergence versus divergence in the global economy.

ANSWER: The 1960 distribution is still quite skewed to the right. Its center seems to be somewhere near the $4000 range, which is much lower than in 2000. Also, whereas the 2000 histogram was bimodal (two little mountains) the 1960 histogram is unimodal (there is just one main mass of countries). The countries all look a lot poorer and there are a lot fewer of those very rich countries.

Whereas in 2000 there is a group of very well-to-do countries, the countries look more similar to one another in 1960. This seems to show that convergence is not happening. The differentiation between the rich and the poor is growing, not shrinking, so there seems to be divergence.

3. Briefly explain what is meant by unconditional economic convergence. What forces might be expected to promote convergence (for example, why does the Solow model suggest convergence might occur while the Harrod-Domar model suggests that it will not occur)? What forces might be expected to retard convergence?

ANSWER: Unconditional convergence assumes that all countries grow towards the same level of income. In a world with large income differences, convergence can only happen if initially poorer countries grow faster than initially richer countries (so that the initially poorer countries can catch up and converge).

Diminishing returns to capital (as in the Solow model) will promote convergence. Diminishing returns means that already rich countries will get lower additional returns from additional investment (less bang for the investment buck!) than will poor countries. These different marginal returns to investment and capital accumulation will tend to slow down growth in the richer countries and speed it up in poorer countries—exactly what is needed for convergence!

If returns to capital do not diminish (as in the Harrod-Domar model), then returns to the investment buck remain the same and there is no force to slow down the rate of growth in rich countries. Non-diminishing returns to capital thus tends retard convergence.

In addition to this core factor of diminishing (or non-diminishing returns) to capital, differences in savings rates, population growth rates and rates of depreciation will also affect whether poorer countries will catch up and converge with richer countries. Even in the Solow model (which assumes that returns to capital diminish), poor countries will not catch up if they have lower savings rates or higher population growth rates. In this case, poor countries and rich countries will grow toward different steady states and convergence will not occur.

Finally, if poorer and richer countries have access to different technologies, then convergence will also not occur.

4. The file PSET2-06.XLS also includes a worksheet labeled Growth. Open that and calculate the average rate of growth of per-worker GDP for each country in the sample over the 1965 to 2000. (See page 10 of the Weil textbook for the formula to calculate growth rates.) Please put your growth rates into the empty column D in the spreadsheet (already labeled Growth, 65-00) as that will make your graphing life easier.

    a. Divide countries into two groups: those with 1965 per-capita GDP below the world average per-capita GDP for 1965 and those with per-capita GDP above the 1965 world average. For each of these two groups, calculate measures of central tendency for the growth rate (mean and median), as well as a measure of dispersion (standard deviation). Are the growth rates of the two groups statistically different from each other? Please

carefully explain your reasoning.

ANSWER: You can calculate the average growth rate using the formula: $g = (\frac{y_{t+n}}{y_t})^{1/n} - 1$ which in this case is equivalent to: $g = (\frac{y_{2000}}{y_{1965}})^{1/35} - 1$.

The measures of central tendency and spread for the two groups are shown below. As can be seen, the average annual growth rate for the set of initially less well-off countries is 1.48% while that for initially better off countries is slightly higher at 1.58%. Note also that the gap between median growth rates (1.34% versus 1.58%) is even large than the gap between mean growth rates for the two groups of countries. Interestingly, the variance of the growth rate for initially richer countries is lower (0.00017) than the growth rate variance for initially poorer countries, indicating that the poorer group had more variable growth.

One way to judge the amount of dispersion is to calculate what is called the coefficient of variation, which is defined as the standard deviation divided by the mean. Recall that the standard deviation is simply the square root of the variance. For poor countries, the coefficient of variation is 1.12 (=0.01667/0.1482), while the coefficient of variation for richer countries is 0.84 (=0.0133/0.158). In other words, the standard deviation of growth rates for initially poor countries is 112% of the mean growth rate, whereas that same statistic for initially rich countries only 84%.

We can use a t-test to see if the 0.1% difference in mean growth rates is sufficiently large so that we can be confident that the rates really are different. As can be seen in the table below, this difference is not statistically significant as we cannot reject the hypothesis that the growth rates are the same (and that the observed 0.1% difference is just random noise). We reach this conclusion because the t-statistic that permits us to test this hypothesis (under the assumption of equal variance) is -0.375. The p-value for this t-statistic is 0.75. We thus cannot reject the hypothesis that the true growth rates are the same. Note that we assume our sample is a good representation of the world.

Central Tendency and dispersion

	Below average	Above average
Mean	0.0148	0.0158
Median	0.0134	0.0158
S.D.	0.0167	0.0133
C.V.	1.1254	0.8396

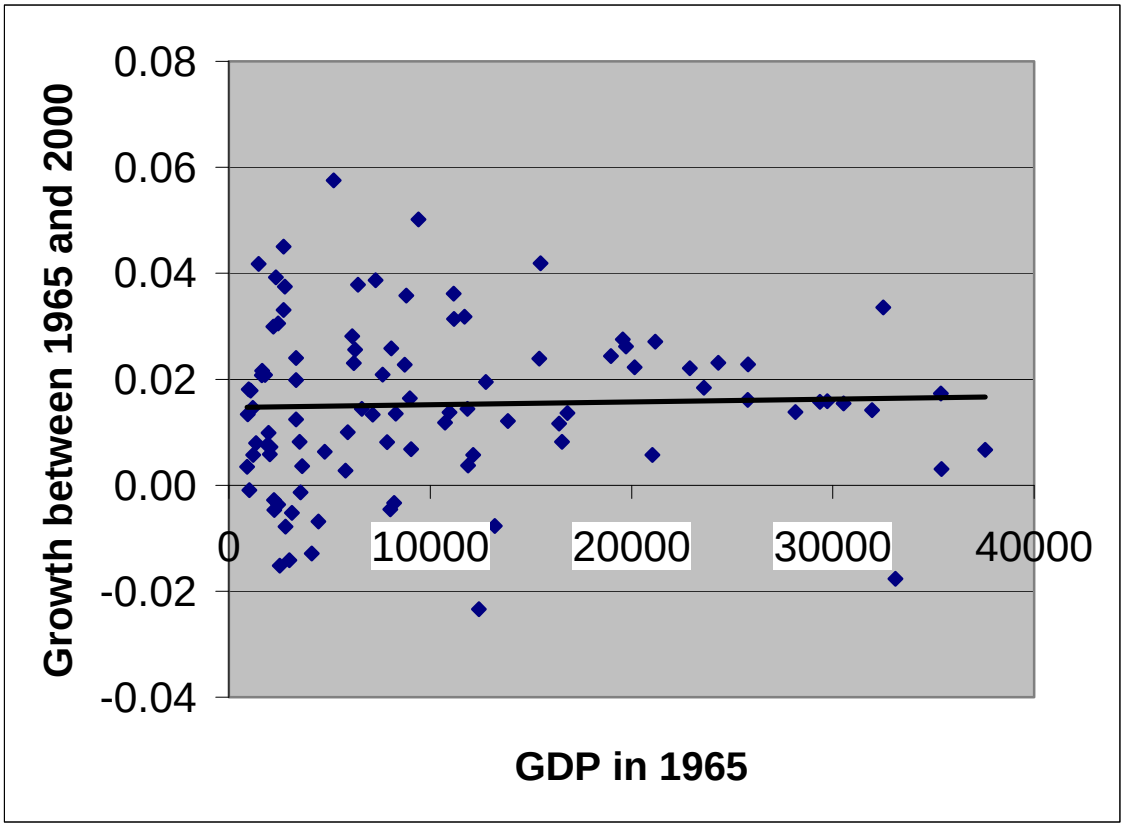
t-Test: Two-Sample Assuming Equal Variances

	Below average	Above average
Mean	0.014820873	0.015845622
Variance	0.000278188	0.000176997
Observations	59	38
Pooled Variance	0.000238777	
Hypothesized Mean Difference	0	
df	95	
t Stat	-0.31882587	
P(T<=t) one-tail	0.375279245	
t Critical one-tail	1.661051818	
P(T<=t) two-tail	0.75055849	
t Critical two-tail	1.985250956	

b. Prepare a scatter diagram that plots growth rates (on the y-axis) against 1965 income levels on the x-axis. To create this scatter diagram, highlight the "GDP/worker, 1965"

and the "Growth, 65-00" columns. Click the "Chart Wizard icon on the toolbar (alternatively, go to the insert menu and select chart). Next select "XY (scatter)" as your plot type. If you have selected the data columns before entering chart wizard, it should correctly make your chart showing 1965 GDP/worker on the x or horizontal axis and the 65-00 Growth Rate on the y or vertical axis. Then add in a trend line.

ANSWER: I have pasted below the graph with the trend line.



c. Please discuss any patterns apparent in your scatter diagram. Does it appear to support unconditional convergence? Does it show divergence, or any other visible pattern? Or is it just a "mess"?

ANSWER: Basically it just looks like a big mess. I don't see much evidence for unconditional convergence. On the other hand, I don't see much evidence for divergence. As the basically flat trend line shows, there is no fundamental relationship between GDP in 1965 and subsequent growth rates. We don't see richer countries growing faster or poorer countries growing faster.

However, as discussed above, we do see more variance in the growth rates of the poorer countries. Some are growing really fast and catching up, and some are growing extremely slowly or even shrinking so they are getting poorer. This speaks to the heterogeneity of experiences of the poorer countries, and encourages us to ask what it is different about those initially poor countries that grew quickly versus those that did not.

5. Suppose that environmental regulations lead to a diversion of investment spending from investments that boost the capital stock to investments that decrease pollution. In the Solow model, what would be the consequences on the economy's steady-state levels of capital and income? What would be the effect on the economy's measured growth rate of GDP and on its capital-output ratio? Would it make sense to say that these environmental regulations diminished economic well-being?

ANSWER: Environmental regulation which leads to a diversion of investment from boosting the capital stock to decreasing pollution would look, in the Solow model, like a decrease in the savings rate. We saw in class that this will lower the steady-state level of capital and income. Assuming the country was originally in its steady state, then when these environmental regulations first take effect the country will experience negative growth (shrink). When the country reaches its new, lower, steady-state it will stop shrinking. This will decrease the capital-output ratio. Before the regulations the country had more capital, after the regulations the country has less capital. Because of diminishing returns to capital, this smaller quantity of capital will be more productive. This means that the capital-output ratio will be lower (it takes less capital to make the same amount of output.

It is hard to say that these environmental regulations diminish the economy's wealth. Pollution is not considered in most measures of GDP and output per worker. If pollution were considered a 'bad' which lowered a nation's wealth then lowering pollution would increase wealth (all else equal). To figure out if the country's wealth was really lowered one would need to know the cost of the pollution-decreasing investment and the economic value of the quantity of pollution it was able to decrease. (If you are interested in learning how to do this, take the Environmental Economics course.)