BUSINESS CYCLES

Introduction

We now turn to the study of the macroeconomy in the short run. In contrast to our study thus far where we were analysing the data over periods of 10 years in length, we will be looking at the data over much shorter periods of time of a year or less. Indeed, for the purpose of the short-run, the preferred frequency of data is at the quarterly level.

The main objective of this chapter is to describe the ways by which the profession has gone about documenting the properties of an economy over the short-run, and summarizing the properties. There is no single way of doing this. In fact, there are two dominant approaches in use for documenting the business cycle properties. The first has a much longer history and goes under the heading of Business Cycle dating. The other is fairly new and goes under the heading of Business Cycle Regularities.

Business Cycle Dating

Business Cycle dating has a long history in economics. It is based on the pioneer work of the American economist, Wesley C. Mitchell (1913, 1922). Although these early works introduced Mitchell's idea of the business cycle being a recurring phenomenon with four distinct phases, his clearest definition appears in a work with Arthur burns in 1946. On page 3, Burns and Mitchell define the business cycle as

> *…a cycle consist of expansion occurring at about the same tin in many economic activities, followed by similarly general recession, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent*

> *but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own.*

Thus, in this very traditional view, the business cycle is a recurring but non-periodic phenomenon that consists of four distinct phases: the expansion, the peak, the contraction and the trough.

This view of business cycles is the driving idea behind *Business Cycle Dating*, certainly the longest used method for documenting the business cycle properties. In Business Cycle Dating, the idea is to take the time series for GDP and determining the dates at which one cycle begins and ends. For the US economy, the responsibility of dating cycles lies with the National Bureau of Economic Research. The following table is taken from their webpage:

All total there have been 33 cycles for the US economy since 1854 with an average duration of 56 months. Interestingly, the length of the cycles shows a general increase upward from 49 months in the 1854-1919 period, to 53 months in the 1910-1945 period to 70 months in the 1945-2009 period. More interestingly is the fact that the increase in the cycle's duration has come at the expense of the contractionary phase. Whereas in the pre-World War I era, the average contraction lasted close to two years, in the post-World War II era contractions have lasted less than a year on average. The expansion has nearly doubled in length, from roughly two years in the early period to roughly 6 years in the latter period.

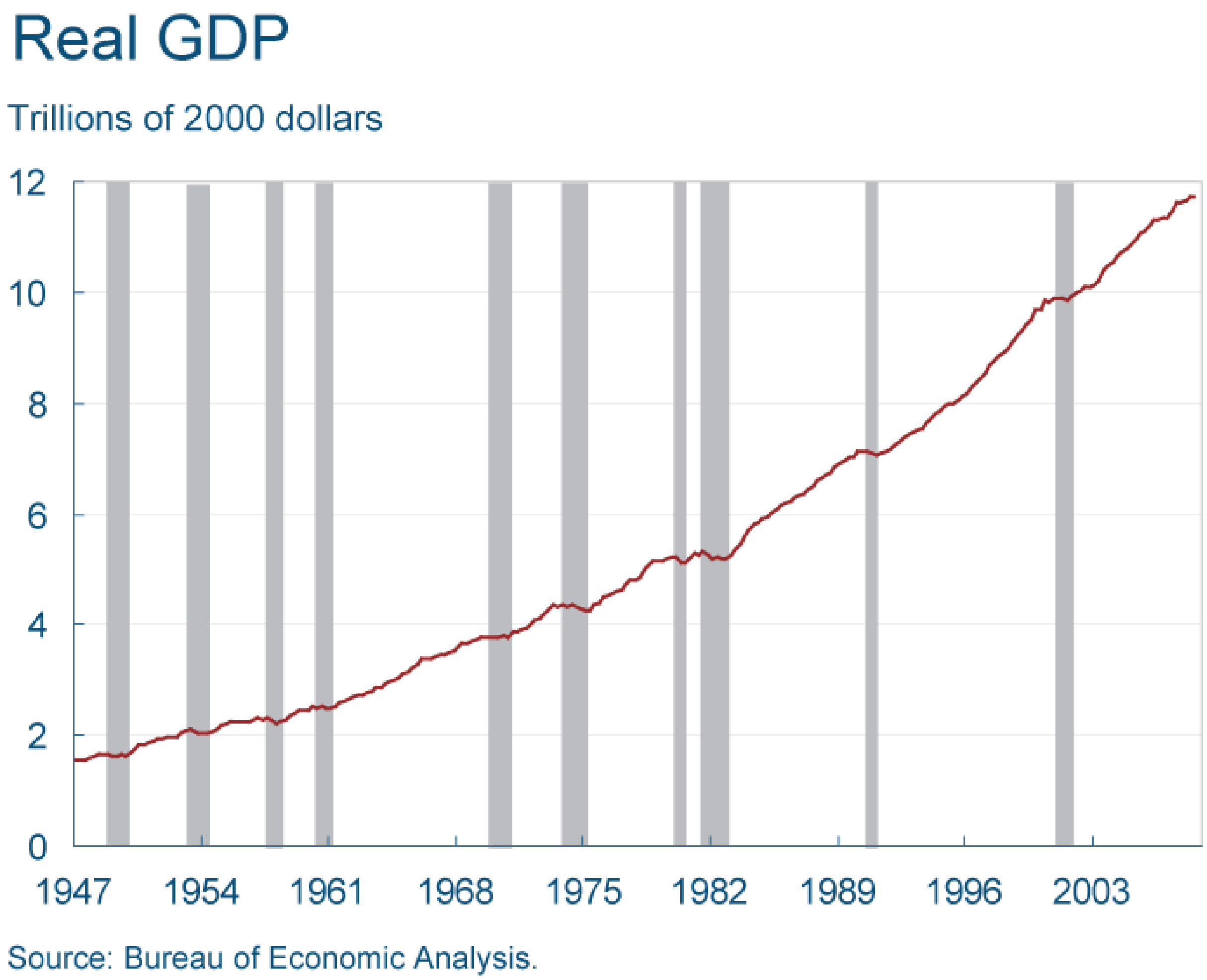
Table 1

BUSINESS CYCLE REFERENCE DATES		DURATION IN MONTHS			
Peak	**Trough**	**Contraction**	**Expansion**	**Cycle**	
Quarterly dates are in parentheses		*Peak to Trough*	*Previous trough to this peak*	*Trough from Previous Trough*	*Peak from Previous Peak*
	December 1854 (IV)	--	--	--	--
June 1857(II)	December 1858 (IV)	18	30	48	--
October 1860(III)	June 1861 (III)	8	22	30	40
April 1865(I)	December 1867 (I)	32	46	78	54
June 1869(II)	December 1870 (IV)	18	18	36	50
October 1873(III)	March 1879 (I)	65	34	99	52
March 1882(I)	May 1885 (II)	38	36	74	101
March 1887(II)	April 1888 (I)	13	22	35	60
July 1890(III)	May 1891 (II)	10	27	37	40
January 1893(I)	June 1894 (II)	17	20	37	30
December 1895(IV)	June 1897 (II)	18	18	36	35
June 1899(III)	December 1900 (IV)	18	24	42	42
September 1902(IV)	August 1904 (III)	23	21	44	39
May 1907(II)	June 1908 (II)	13	33	46	56
January 1910(I)	January 1912 (IV)	24	19	43	32
January 1913(I)	December 1914 (IV)	23	12	35	36
August 1918(III)	March 1919 (I)	7	44	51	67
January 1920(I)	July 1921 (III)	18	10	28	17
May 1923(II)	July 1924 (III)	14	22	36	40
October 1926(III)	November 1927 (IV)	13	27	40	41
August 1929(III)	March 1933 (I)	43	21	64	34
May 1937(II)	June 1938 (II)	13	50	63	93
February 1945(I)	October 1945 (IV)	8	80	88	93
November 1948(IV)	October 1949 (IV)	11	37	48	45
July 1953(II)	May 1954 (II)	10	45	55	56
August 1957(III)	April 1958 (II)	8	39	47	49
April 1960(II)	February 1961 (I)	10	24	34	32
December 1969(IV)	November 1970 (IV)	11	106	117	116
November 1973(IV)	March 1975 (I)	16	36	52	47
January 1980(I)	July 1980 (III)	6	58	64	74
July 1981(III)	November 1982 (IV)	16	12	28	18
July 1990(III)	March 1991(I)	8	92	100	108
March 2001(I)	November 2001 (IV)	8	120	128	128
December 2007 (IV)	June 2009 (II)	18	73	91	81
Average, all cycles:					
1854-2009 (33 cycles)		17.5	38.7	56.2	56.4*
1854-1919 (16 cycles)		21.6	26.6	48.2	48.9**
1919-1945 (6 cycles)		18.2	35.0	53.2	53.0
1945-2009 (11 cycles)		11.1	58.4	69.5	68.5

* 32 cycles
** 15 cycles

Source: NBER

The following figure reprinted from the *Bureau of Economic Analysis* shows US GDP from 1947 until 2005. The shaded areas are the recessionary phases as determined by the NBER dating group. Although the figure does not show the early period and hence the dramatic decline in the length of the contractionary phase over time, it does make it clear how rare recessions have been since the early 1980s. Of course, the figure fails to include the Great Recession that began in 2007.



Business Cycle Regularities

An alternative view to business cycles was offered by Robert E. Lucas in a 1977 article titled *Understanding Business Cycles*. Lucas defined the business cycles as deviations of GDP about its trend. He further went on to define business cycle regularities to mean comovements of deviations of other time series from their trends with the deviations of output from its trend.

The reason Lucas gives for breaking with the traditional approach of dating the business cycle is that economists going back to Eugen Slutzky (1927) have understood that that the time series of GDP is well-approximated by a low order stochastic difference equation with a random term. For example, let y_t be the variable of interest in period t and assume that y evolves according to the following equation:

$$y_{t+1} = .95y_t + \varepsilon_{t+1} \qquad (1)$$

This is an example of a first order stochastic difference equation. It is first order because the difference in the time subscripts for the y's in the equation is one. (If the left hand side included y_{t-1} then difference equation would be second order). It is stochastic because the term ε_{t+1} is a random variable.

Lucas's definition of the business cycle was made operational by Kydland and Prescott (1990). One shortcoming of Lucas's definition was that it did not define what was meant by trend. Kydland and Prescott (1990) rectified this failure. For them, the idea of trend was the balanced growth path of the Neoclassical growth model with the rate of increase of per capita GDP equal to the rate of technological change.

Although the theory assumed that technology grew at the same rate every period, Kydland and Prescott were not naïve to think that it applied in reality. Hence, they did not impose that the trend of a time series be a straight line in its logarithmic representations. Instead, Kydland and Prescott defined trend to be roughly a straight line that should not change if the period of analysis were either shortened or lengthened and that should not involve any human judgement.

The algorithm used by Kydland and Prescott to compute the trend of a time series and also its deviations is known as the Hodrick-Prescott filter. The Hodrick-Prescott filter (HP) works as follows: Let Y_t be some variable at time t, and let y_t be the logarithm of that variable at time t. Let τ_t denote the trend (logarithm) of the variable. In the HP filter, the time series of y_t is known and the objective is to find the trend. The HP filter chooses the trend to minimize the following

$$\sum_{t=1}^{T}(y_t - \tau_t)^2 + \lambda\sum_{t=1}^{T}[(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2 \qquad (2)$$

The first terms is the sum of the squared deviations. The second term is effectively the penalty or constraint associated with not having the trend be a linear function. The value of λ determines the weight on the penalty term and determines the extent to which the trend is a straight linear function. If we assign $\lambda = +\infty$, then the penalty term has such a huge weight that we will set $(\tau_{t+1}-\tau_t) = (\tau_t - \tau_{t-1})$, i.e. a straight line. If in contrast we assign $\lambda=0$, then the trend is equal to output as there is no penalty with changing the slope of the trend line, i.e., $y_t = \tau_t$.

For the purpose of detrending data at the quarterly frequency, the value that is assigned to λ in the HP algorithm is 1600. If we were to use annual data, there is far less agreement as to what is the appropriate value for the smoothing parameter. Some studies set $\lambda = 6.5$ whereas others set $\lambda = 100$.

In documenting the business cycle properties, the first step is to find the trend of each time series, $\{\tau_t\}$ and its deviations $\{d_t=y_t-\tau_t\}$. The business cycle documentation focusses on three aspects of the detrended data. The first is a measure of the amplitude, or size of the deviation from its trend, the so called volatility. For this purpose the steps are to first express the deviation as a percentage of the trend, namely, define $x_t = d_t/\tau_t$. Next, we take the standard deviation of the (percentage) deviation from trend. This is the measure of volatility. It is measured as a percentage of the trend, not the absolute size of the deviation. This is important to note as we shall see later on that investment as a percentage of its trend is about 3 times more volatile than GDP. In absolute terms, since investment is only about 25 percent of GDP, its volatility is smaller.

The second property is the comovement of the deviations of each variable from its trend with the deviations of output from its trend. For this purpose, we calculate the correlation coefficient between d_{xt} and d_{yt} where d_{xt} is the deviation of variable x from its trend and d_{yt} is the deviation of variable y from its trend. The formulas for the correlation coefficient is

$$\rho(d_{xt}, d_{yt}) = \frac{\sum (d_{xt} - \bar{d}_x)(d_{yt} - \bar{d}_y)}{\sqrt{\sum (d_{xt} - \overline{d_x})^2}\sqrt{\sum \ (d_{yt} - \overline{d_y})^2}} \qquad (3)$$

The correlation coefficient takes on values between +1 and -1. It represents the degree to which the two variables are related by a straight line. Thus, if $\rho = 1$, the two variables line up on a straight line with a positive slope. For variables in which the correlation coefficient is close to one, we use the word procyclical to characterize their relationship; when the x variable is above its trend so is output. If ρ=-1, then the two variables are linearly related but the slope is negative. In this case, we say the variable x is countercyclical; when x is above its trend, output tends to be below its trends. The closer ρ is to zero, the less of any linear relation between the two variables.

The final measure in documenting the business cycle properties is also based on computing correlation coefficients, but it is done with the intent of determining whether a variable leads or lags the output series. For the purpose of determining if a series leads output we calculate the correlation coefficient between d_{xt-j} and d_{yt} and for the purpose of determining if a series lags output we calculate the correlation coefficient between d_{xt+j} and d_{yt}. The value of j typically ranges between 1 and 4 when dealing with quarterly data. Thus, one is considering lags and leads of one year or less.

The following tables are based on Kydland and Prescott (1990). Table 2 is organized around the uses of GDP, namely, GDP=C+I+G+Nx. The most striking features of the table are volatility of the investment time series. As seen in column 2, it is roughly 3 times more volatile than output. Recall, that the volatility is not in absolute dollar terms but as a percentage of a trend. With the exception of residential investment, each sub category of investment is most strongly positively correlated with contemporaneous deviations in output, or lags the cycle by a quarter. Residential Investment leads the cycle with by a quarter or half year. This should not be surprising as Residential Investment, (i.e;, New Housing) is a heavily referenced leading indicator in the news.

Table17.2

Cyclical behavior of U.S. output and income components(deviations from trend of product and income variables, quarterly,1954-1989)

		Cross Correlation of Real GNP with										
Variable x	Volatility (% std.dev.)	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Real Gross National Product	1.71	-0.03	0.15	0.38	0.63	0.85	1.00	0.85	0.63	0.38	0.15	-0.03
Consumption Expenditures	1.25	0.25	0.41	0.56	0.71	0.81	0.82	0.66	0.45	0.21	-0.02	-0.21
Nondurables and services	0.84	0.20	0.38	0.53	0.67	0.77	0.76	0.63	0.46	0.27	0.06	-0.12
Nondurables	1.23	0.29	0.42	0.52	0.62	0.69	0.69	0.57	0.38	0.16	-0.05	-0.22
Services	0.63	0.03	0.25	0.46	0.63	0.73	0.71	0.60	0.49	0.39	0.23	0.07
Durables	4.99	0.25	0.38	0.50	0.64	0.74	0.77	0.60	0.37	0.10	-0.14	-0.32
Investment Expenditures	8.30	0.04	0.19	0.39	0.60	0.79	0.91	0.75	0.50	0.21	-0.05	-0.26
Fixed Investment	5.38	0.09	0.25	0.44	0.64	0.83	0.90	0.81	0.60	0.35	0.08	-0.14
Nonresidential	5.18	-0.26	-0.13	0.05	0.31	0.57	0.80	0.88	0.83	0.68	0.46	0.23
Structures	4.75	-0.40	-0.31	-0.17	0.03	0.29	0.52	0.65	0.69	0.63	0.50	0.34
Equipment	6.21	-0.18	-0.04	0.14	0.39	0.65	0.85	0.90	0.81	0.62	0.38	0.15
Residential	10.89	0.42	0.56	0.66	0.73	0.73	0.62	0.37	0.10	-0.15	-0.34	-0.45
Government Purchases	2.07	0.00	-0.03	-0.03	-0.01	-0.01	0.05	0.09	0.12	0.17	0.27	0.34
Federal	3.68	0.00	-0.05	-0.08	-0.09	-0.09	-0.02	0.03	0.06	0.10	0.19	0.24
State and Local	1.19	0.06	0.10	0.17	0.25	0.26	0.25	0.20	0.16	0.19	0.27	0.36
Exports	5.53	-0.50	-0.46	-0.34	-0.14	0.11	0.34	0.48	0.53	0.53	0.53	0.45
Imports	4.92	0.11	0.18	0.30	0.45	0.61	0.71	0.71	0.51	0.28	0.03	-0.19
Real Net National Income												
Labor Income*	1.58	-0.18	-0.02	0.18	0.42	0.68	0.88	0.90	0.80	0.62	0.40	0.19
Capital Income**	2.93	0.10	0.24	0.44	0.63	0.79	0.84	0.60	0.30	0.02	-0.19	-0.29
Proprietors' Income and Misc.+	2.70	0.11	0.24	0.38	0.55	0.62	0.68	0.46	0.29	0.11	0.02	-0.10

Personal Consumption Expenditures are also procyclical but less volatile than output. This makes sense from the standpoint of theory. Consumer utility maximization is based on the idea that individuals prefer smooth consumption streams. Interestingly, the durable component category of Consumption Expenditures is as volatile as investment expenditures. To the extent that household durable purchases are investment goods this finding is not surprising.

Government expenditures show very little contemporaneous variation with the business cycle. State and local government expenditures are more strongly procylical than expenditures by the federal government. This makes sense in light of what we learned earlier about the inability of state governments to print money and how this leads to US states running fewer deficits than the Federal government. Imports are strongly procyclical. Imported goods are bought by consumers and businesses and to the extent that consumption expenditures and investment expenditures are procyclical, imports will be also procyclical.

The next Table is organized around the inputs and output of the economy. Importantly, labor input as measured by total hours is less volatile than output and strongly procyclical. There are two independent measures of total hours in the United States, Household surveys and Establishment Surveys. The Household survey shows less volatility. The Household survey also breaks total hours into employment and hours per worker. What is interesting to note here is that employment is procyclical with a lag of one quarter whereas hours per worker is contemporaneously procyclical. This suggests that firms respond initially to an increase in demand for their product by having current workers work longer hours. They then respond by adding workers with a three month lag.

Table17.1
Cyclical behavior of U.S. production inputs(deviations from trend of input variables, quarterly,1954-1989)

Variable x	Volatility (% std.dev.)	Cross Correlation of Real GNP with										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Real Gross National Product	1.71	-0.03	0.15	0.38	0.63	0.85	1.00	0.85	0.63	0.38	0.15	-0.03
Labor Input												
Hours (Household Survey)	1.47	-0.10	0.05	0.23	0.44	0.69	0.86	0.86	0.75	0.59	0.38	0.18
Employment	1.06	-0.18	-0.04	0.14	0.36	0.61	0.82	0.89	0.82	0.67	0.47	0.25
Hours per Worker	0.54	0.08	0.21	0.35	0.49	0.66	0.71	0.59	0.43	0.29	0.11	-0.02
Hours (Establishment Survey)	1.65	-0.23	-0.07	0.14	0.39	0.66	0.88	0.92	0.81	0.64	0.42	0.21
GNP/Hours (Household Survey)	0.88	0.11	0.21	0.34	0.48	0.50	0.51	0.21	-0.02	-0.25	-0.34	-0.36
GNP/Hours (Establishment Survey)	0.83	0.40	0.46	0.49	0.53	0.43	0.31	-0.07	-0.31	-0.49	-0.52	-0.50
Average Hourly Real Compensation (Business Sector)	0.91	0.30	0.37	0.40	0.42	0.40	0.35	0.26	0.17	0.05	-0.08	-0.20
Capital Input												
Nonresidental Capital Stock*	0.62	-0.58	-0.61	-0.51	-0.48	-0.31	-0.08	0.16	0.39	0.56	0.66	0.70
Structures	0.37	-0.45	-0.51	-0.55	-0.53	-0.44	-0.29	-0.10	0.09	0.25	0.38	0.45
Producers' Durable Equipment	0.99	-0.57	-0.58	-0.53	-0.41	-0.22	0.02	0.26	0.47	0.62	0.70	0.71
Inventory Stock (nonfarm)	1.65	-0.37	-0.33	-0.23	-0.05	0.19	0.50	0.72	0.83	0.81	0.71	0.53

The capital input show very little correlation with output is far less volatile. This makes sense. Today, the capital stock is essentially fixed and cannot be increased or decreased (although one can certainly keep equipment idle on the shelf. Although not contemporaneously related to output deviations, the capital input has a strong positive correlation with a lag of 1 year to 1.25 years. This makes sense in light of investment expenditures being strongly and contemporaneously procyclical. It takes time to build new machines and new structures.

The table also shows how output per work hour, a proxy for productivity, and average hourly real compensation, a proxy for real wages) move with output. Each of these series is about half as volatile as output and each is contemporaneously procyclical. At the time of the article, these findings were surprising as they were in conflict with the predictions of the Keynesian macro model of the pre-1970 era.

The final Table in the Kydland and Prescott article examines the volatility and correlations between monetary variables. They consider three monetary aggregates: the monetary base, M1 and M2. The monetary base consists of the total amount of currency either held in the hands of the public or in a deposit of a commercial bank at the central bank. M1 consists of money held by the public, travelers checks and demand deposits (i.e., checking accounts). M2 includes all of M1 plus savings deposits and time deposits less than $100,000. The monetary base is the measure of the money supply that is central bank has most control of. M1 is the value of financial assets that primarily serve as a medium of exchange. M2 includes the value of financial assets that serve as a store of wealth. All are procyclical, but moderate in their correlations. The strongest correlation is with M2 with a lead of one half to three fourths of a year. For the price level, the key finding is that it is countercyclical; when output is above its trend, prices are below its trend. Again, this is a finding that stands in sharp contrast to the Keynesian model that had dominated the pre-1970 era.

Table17.4
Cyclical behavior of U.S. monetary aggregates and the price level(deviations from trend of money stock, velocity, and price level, quarterly,1954-1989)

	Volatility	Cross Correlation of Real GNP with										
Variable x	(% std.dev.)	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Nominal Money Stock												
Monetary Base	0.88	-0.12	0.02	0.14	0.25	0.36	0.41	0.40	0.37	0.32	0.28	0.26
M1	1.68	0.01	0.12	0.23	0.33	0.35	0.31	0.22	0.15	0.09	0.07	0.07
M2	1.51	0.48	0.60	0.67	0.68	0.61	0.46	0.26	0.05	-0.15	-0.33	-0.46
M2-M1	1.91	0.53	0.63	0.67	0.65	0.56	0.40	0.20	-0.01	-0.21	-0.39	-0.53
Velocity*												
Monetary Base	1.33	-0.26	-0.15	0.00	0.22	0.40	0.59	0.50	0.37	0.22	0.08	-0.08
M1	2.02	-0.24	-0.19	-0.12	-0.01	0.14	0.31	0.32	0.27	0.20	0.10	0.00
M2	1.84	-0.63	-0.59	-0.48	-0.29	-0.05	0.24	0.34	0.40	0.43	0.44	0.43
Price Level												
Implicit GNP Deflator	0.89	-0.50	-0.61	-0.68	-0.69	-0.64	-0.55	-0.43	-0.31	-0.17	-0.04	0.09
Consumer Price Index	1.41	-0.52	-0.63	-0.70	-0.72	-0.68	-0.57	-0.41	-0.24	-0.05	0.14	0.30

There is much debate whether monetary policy has real effects on the economy. Although M2 was found to leads real GDP in the 1954-89 period, this does not mean that changes in the money supply cause changes in real output. The numbers in the table are correlations, and hence do not say anything about causation. In fact, King and Plosser argued that the positive lead documented by Kydland and Prescott could actually reflect causation from future output to M2, what is called *reverse causation*.

Basically, the story is that people understand or believe that the economic activity will pick up in three months or six months from now. As a result, they may want to take out a loan to buy a new suit, or extra uniform so they can be ready for the upturn. If banks were holding excess reserves, currency in their own vaults or the central bank's vault above the legal requirement, they can meet this increase in demand for loans with these funds. How much money there is in the economy depends on the behaviour of both households as to how much money they hold in their pocket and banks as to how many excess reserves they hold. If households put less money in their pockets and more in their checking or savings accounts and if banks hold less excess reserves, the money supply will be higher given the same monetary base.

Conclusion

To be written

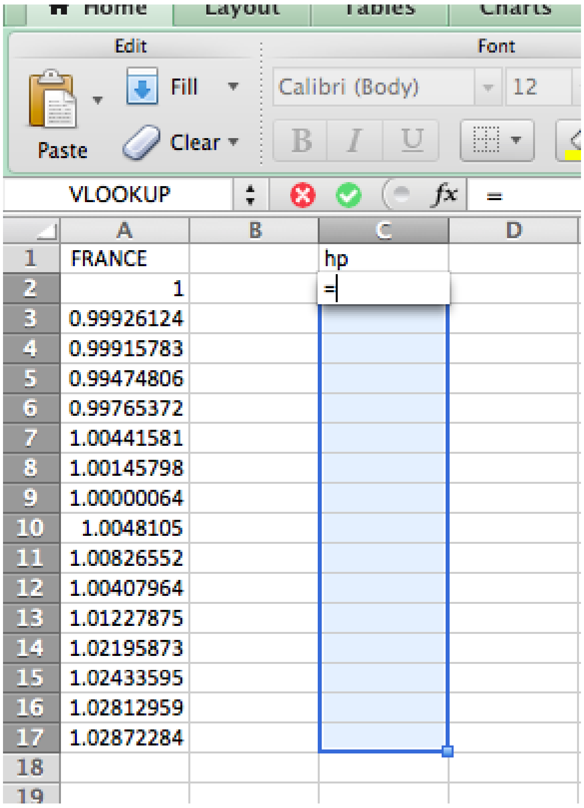
Appendix: Installing the Hodrick-Prescott Filter
Kurt Annen has written a free-download of the HP-Filter for Excel.

To add the HP filter to your excel spreadsheet first go to the web page: http://www.web-reg.de/hp/hp.htm. From there, follow the instruction to download the HP filter to your computer. The files will be installed in zip file. Open the file "hpfilter.zip" and extract the three files within. Then open the file "HP-Example.xls" and follow the instructions to install. (Note: that for Microsoft Excel 2010 you will have to go File – Options- Add-Ins as there is no Tools Menu)

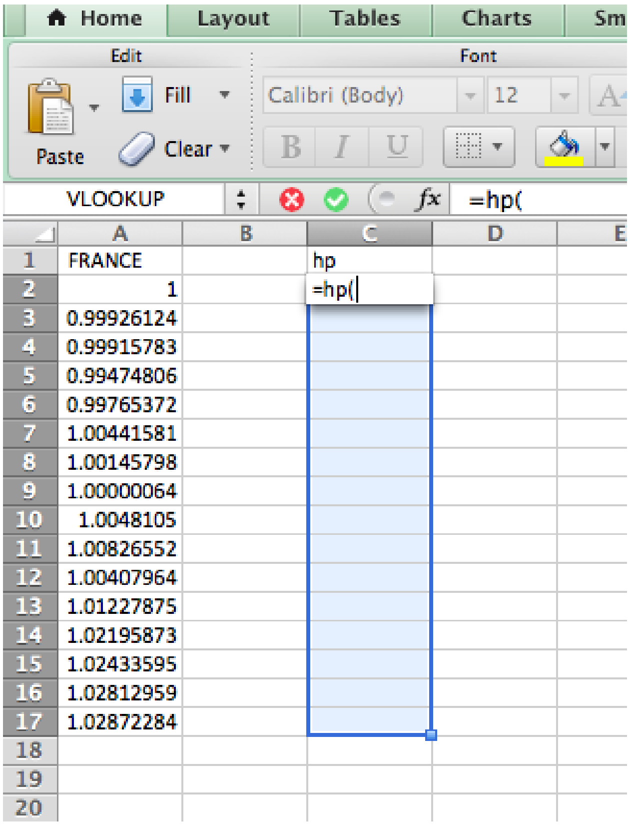
Using the HP Filter in Excel

After installing the HP filter in excel, you are ready to detrend any time series using the function HP(). (The St. Louis Federal Reserves website (FRED) is a great site to easily input data into an excel spreadsheet. You can download the Add-In) We illustrate the use of the HP Filter data for a time series that appears in cells A2:A17 in an excel spreadsheet. You can watch a video on the using the HP-Filter by Humberto Barreto.

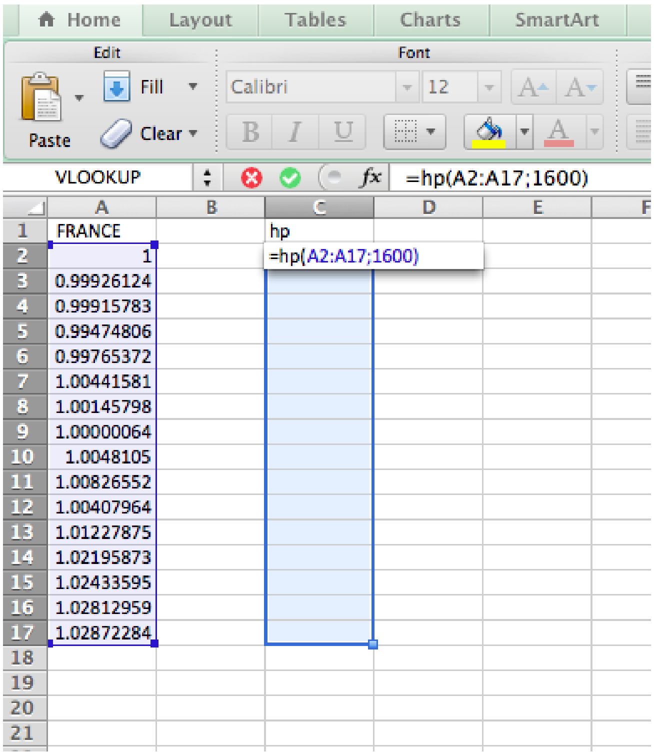
Don't forget to use the logarithm of the time series you want to detrend before Steps1-4.
Step1: Select the block of cells that we want to apply the HP filter to. To compute the trend component in column C, press the Shift key and place the mouse cursor on cell C2 then click cell C17. Make sure the length of the block is identical to the data A2:17.



Step2: Next type in "hp(" in the formula bar.

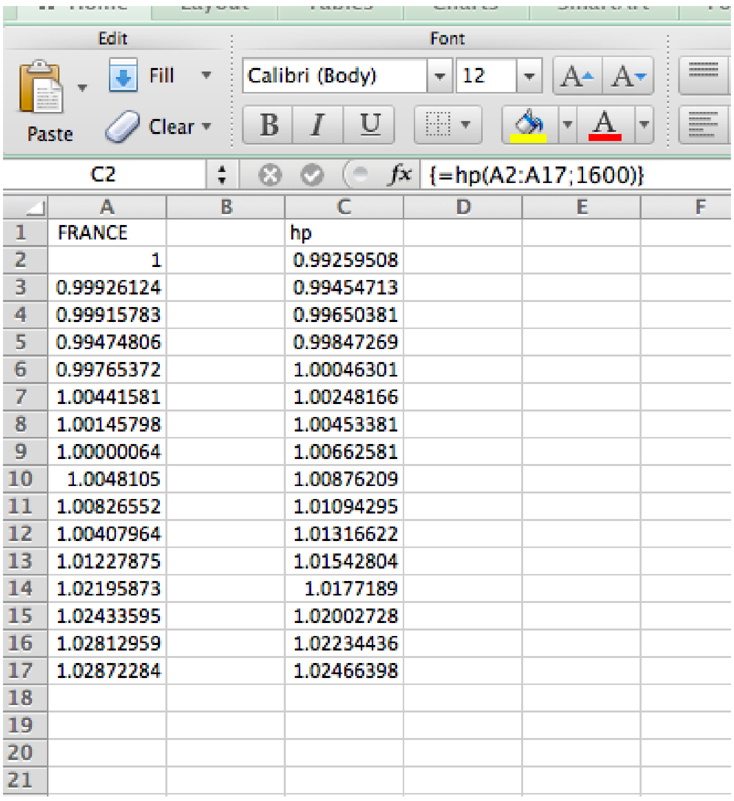


Step 3: Now add the range of block as follows
=hp(A2:A17,1600) and write the smoothing coefficient as follows
Smoothing Coefficient
For annual data: 100
Monthly data:14400
Quarterly data:1600
**NOTE: the spreadsheet image below is incorrect in using a semi-colon ;. The correct formual is above with a comma between A17 and the smoothing parameter.



Step4: Hit the enter key while pressing Shift key and Control key at the same time.

Finally, we get the result. Recall that the hp function returns the trend. To find the deviation, you would subract C2 from A2.



Problem Set: Use the St. Louis Federal Reserve Bank's data website called FRED to input the following data for the US economy into an excel spreadsheet. Choose quarterly data.

Use the Browse Popular Data Releases

Under Gross Domestic Product Icon Download

1. Real GDP (from 1948)
2. Real Personal Consumption Expenditures (from 1948)
3. Real Gross Private Domestic Investment (from 1948)

Under Browse Popular US Data

Under Population, Employment and Labor markets download

1. Unemployment rate (from 1948)

Under Prices download

1. GDP Implicit Price Deflator (from 1948)

Under Money, Banking and Finance download

1. M2 (Starting with 1991)

You are to:

HP Filter each series using the smoothing parameter =1600.

Hand in for each series

1. Volatility
2. Correlation coefficient with deviations in output.