Chapter 1

A First Look at the Data

How volatile is output? Do the components of aggregate demand (consumption, investment, government spending, and exports) move pro or countercyclically? How persistent are movements in aggregate activity? Are economic expansions associated with deficits or surpluses in the trade balance? What about economic contractions? Is aggregate consumption less or more volatile than output? Are emerging countries more or less volatile than developed countries? Does country size matter for business cycles? The answer to these and other similar questions form a basic set of empirical facts about business cycles that one would like macro models of the open economy to be able to explain. Accordingly, the purpose of this chapter is to document these facts using aggregate data on economic activity spanning time and space.

1.1 Measuring Business Cycles

In the theoretical models we study in this book, the basic economic units are the individual consumer, the firm, and the government. The models produce predictions for the consumers' levels of income, spending, and savings and for firms' investment and production decisions. To compare the predictions of theoretical models to actual data, it is therefore natural to consider time series and cross-country evidence on per capita measures of aggregate activity. Accordingly, in this chapter we describe the business-cycle properties of output per capita, denoted y, total private consumption per capita, denoted c, public consumption per capita, denoted g, exports per capita, denoted x, imports per capita, denoted m, the trade balance, denoted $tb \equiv (x-m)/y$, and the current account, denoted ca.

To compute business-cycle statistics we use annual, cross-country, time-series data from the World Bank's World Development Indicators (WDI) data base.[1] All time series are expressed in real per capita terms. Only countries with at least 30 uninterrupted years of data for y, c, i, g, x, and m were considered. The resulting sample contains 120 countries and covers, on average, the period 1965-2010.[2]

A word on the consumption data is in order. The WDI data base contains information on household final consumption expenditure. This time series includes consumption expenditure on non-durables, services, and durables. Typically, business-cycle studies remove expenditures on durables from the definition of consumption. The reason is that from an economic point of view, expenditure on durable consumption goods, such as cars and washing machines, represent an investment in household physical capital. For this reason, researchers often add this component of consumption to the gross investment series. From a statistical point of view, there is also a reason to separate durables from nondurables and services in the definition of consumption. Expenditures on durables are far more volatile than expenditures on nondurables and services. For example, in the United States, durable consumption is about three times as volatile as output, whereas consumption of nondurable and services is less volatile than output. Even though expenditures on durables represent only 13 percent of total consumption expenditure, the standard deviation of total consumption

[1] The data set is publicly available at databank.worldbank.org.

[2] Only 94 countries contained 30 uninterrupted years of current account data.

is 20 percent higher than that of nondurables and services. Unfortunately, the WDI data set does not provide disaggregated consumption data. One should therefore keep in mind that the volatility of consumption reported later in this chapter is likely to be somewhat higher than the one that would result if our measure of consumption excluded expenditures on durables goods.

The focus of our analysis is to understand aggregate fluctuations at business-cycle frequency in open economies. It is therefore important to extract from the raw time series data the associated cyclical component. The existing literature suggests a variety of methods for isolating the cyclical component of a time series. The most popular ones are log-linear detrending, log-quadratic detrending, Hodrick-Prescott (HP) filtering, first differencing, and band-pass filtering. The following analysis uses quadratic detrending, HP filtering, and first differencing.

To extract a log-quadratic trend, we proceed as follows. Let y_t denote the natural logarithm of real output per capita in year t for a given country, y_t^c the cyclical component of y_t, and y_t^s the secular (or trend) component of y_t. Then we have

$$y_t = y_t^c + y_t^s. \tag{1.1}$$

The components y_t^c and y_t^s are estimated by running the following regression

$$y_t = a + bt + ct^2 + \epsilon_t,$$

and setting

$$y_t^c = \epsilon_t$$

and

$$y_t^s = a + bt + ct^2.$$

An identical procedure is used to detrend the natural logarithms of consumption, government spending, exports, and imports and the levels of the trade-balance-to-output ratio and the current-account-to-output ratio. The levels of the trade balance and the current account (tb and ca) first divided by the secular component of output ($e^{y_t^s}$) and then quadratically detrended. We perform the decomposition into cycle and trend for every time series and every country separately.

To illustrate the workings of the log-quadratic filter, we show the decomposition into trend and cycle it delivers for Argentine real GDP per capita over the period 1960-2011. The top panel of figure 1.1 shows with a solid line raw data and with a broken line the estimated quadratic trend, y_t^s. The bottom panel shows the cyclical component, y_t^c. The detrending procedure delivers three well marked cycles, one from the beginning of the sample until 1980, a second one from 1980 to 1998, and a third one from 1998 to the end of the sample. In particular, the log-quadratic filter succeeds in identifying the two major contractions in postwar Argentina, namely the one associated with the hyperinflation of the late 1980s and the one associated with the demise of the Convertibility Plan in 2001. In the first of these contractions, real GDP per capita fell by about 40 percent from the peak in 1980 to the trough in 1990, giving the 1980s the well-deserved nick name of lost decade.

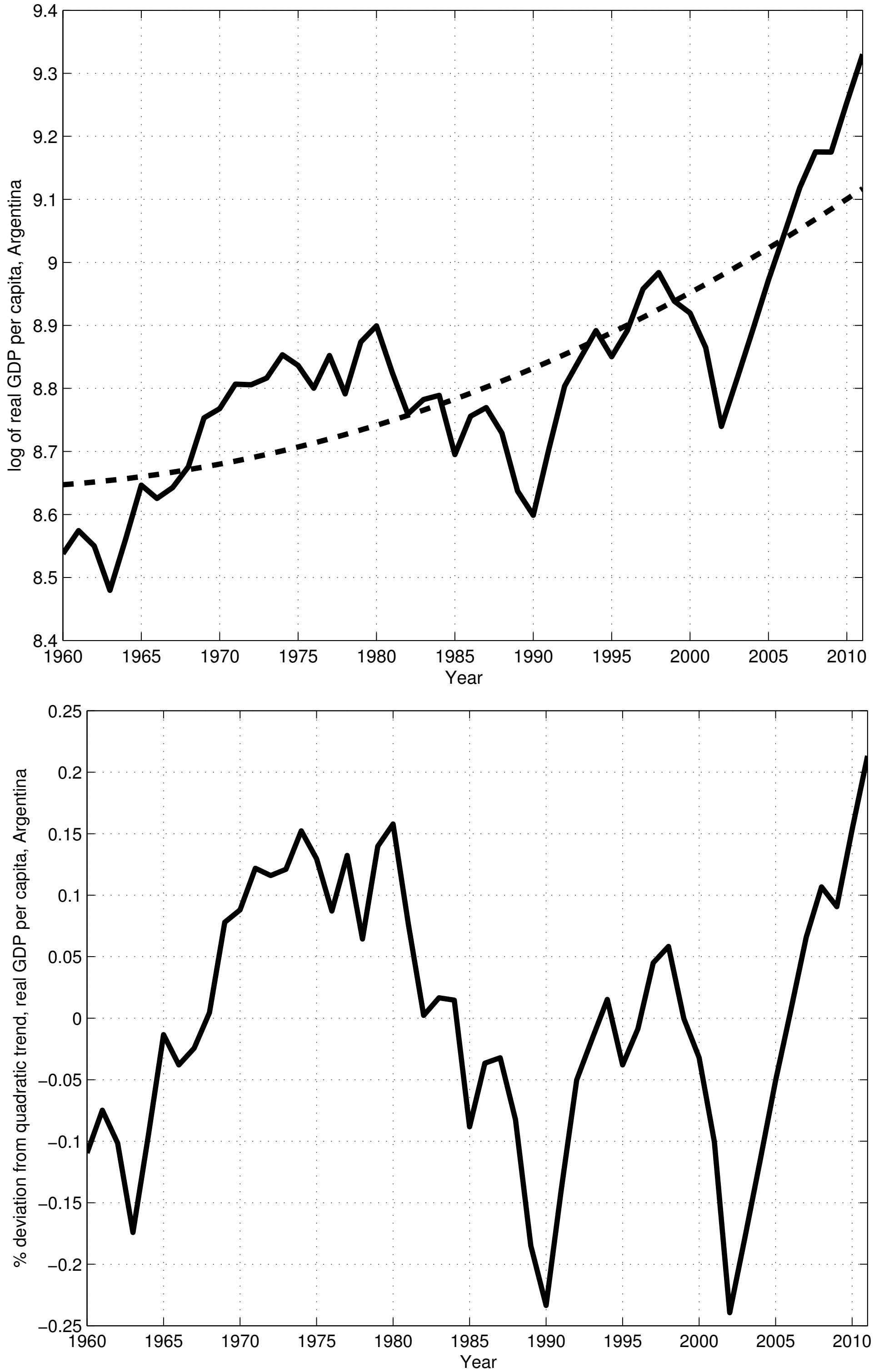
The behavior of the business-cycle component of real GDP suggests that the Argentine economy has been highly volatile over the past 50 years. The standard deviation of y_t^c is 10.7 percent per year. The cyclical component is also quite persistent. The serial correlation of y_t^c is 0.85.

In the next section, we expand this analysis to all macroeconomic aggregates and countries included in our data set.

1.2 Business-Cycle Facts Around The World

To characterize the average world business cycle, we compute business-cycle statistics for each country in the sample and then take a population-weighted average of each statistic across countries.

Figure 1.1: Trend and Cycle of Argentine real GDP per capita: 1960-2011



Data Source: WDI Database and authors calculations.

The resulting average summary statistics appear in table 1.1 under the heading 'All Countries.'

The table displays standard deviations, correlations with output, and serial correlations. Relative standard deviations are cross-country averages of country-specific relative standard deviations. The table also displays averages of the trade-balance-to-output share and the openness ratio, defined as $(x + m)/y$.

According to table 1.1, the world is a pretty volatile place. The average standard deviation of output across all countries is 6.2 percent. To put this number into perspective, we contrast it with the volatility of output in the United States (not shown in the table). The standard deviation of the cyclical component of U.S. output is 2.9 percent, less than half of the average volatility of output across all countries in the data set.

Fact 1.1 (High Global Volatility) *The cross-country average volatility of output is twice as large as its U.S. counterpart.*

One statistic in table 1.1 that might attract some attention is that on average across countries private consumption is 5 percent more volatile than output. This fact might seem at odds with the backbone of optimizing models of the business cycle, namely, consumption smoothing. However, recall that the measure of consumption used here includes expenditures on consumer durables, which are highly volatile. The fact that expenditure on durables is highly volatile need not be at odds with consumption smoothing because it represents an investment in household capital rather than direct consumption. For example, a household that buys a new car every 5 years displays a choppy path for expenditures on cars, but might choose to experience a smooth consumption of the services provided by its car.

The government does not appear to smooth its own consumption of goods and services either. On average, the standard deviation of public consumption is more than twice that of output.

Table 1.1: Business Cycles in Poor, Emerging, and Rich Countries

Statistic	All Countries	Poor Countries	Emerging Countries	Rich Countries
Standard Deviations				
σ_y	6.22	6.08	8.71	3.32
σ_c/σ_y	1.05	1.12	0.98	0.87
σ_g/σ_y	2.26	2.46	2.00	1.73
σ_i/σ_y	3.14	3.24	2.79	3.20
σ_x/σ_y	3.07	3.08	2.82	3.36
σ_m/σ_y	3.23	3.30	2.72	3.64
$\sigma_{tb/y}$	2.34	2.12	3.80	1.25
$\sigma_{ca/y}$	2.16	2.06	3.08	1.39
Correlations with y				
y	1.00	1.00	1.00	1.00
c	0.69	0.66	0.75	0.76
g/y	-0.02	0.08	-0.08	-0.39
i	0.66	0.60	0.77	0.77
x	0.19	0.14	0.35	0.17
m	0.24	0.14	0.50	0.34
tb/y	-0.15	-0.11	-0.21	-0.26
tb	-0.18	-0.14	-0.24	-0.25
ca/y	-0.28	-0.28	-0.24	-0.30
ca	-0.28	-0.28	-0.26	-0.31
Serial Correlations				
y	0.71	0.65	0.87	0.76
c	0.66	0.62	0.74	0.75
g	0.76	0.71	0.80	0.89
i	0.56	0.49	0.72	0.67
x	0.68	0.65	0.74	0.74
m	0.65	0.61	0.74	0.69
tb/y	0.61	0.59	0.62	0.69
ca/y	0.57	0.55	0.52	0.71
Means				
tb/y	-1.3	-1.6	-1.4	-0.0
$(x+m)/y$	36.5	32.5	46.4	40.4

Note. The variables y, c, g, i, x, m, $tb \equiv (x-m)$, and ca denote, respectively, output, total private consumption, government spending, investment, exports, imports, the trade balance, and the current account. All variables are real and per capita. The variables y, c, g, i, x, and m are quadratically detrended in logs and expressed in percent deviations from trend,. The variables tb/y, g/y, and ca/y are quadratically detrended in levels. The variables tb and ca are scaled by the secular component of y and quadratically detrended. The sample contains 120 countries and covers, on average, the period 1965-2010 at annual frequency. Moments are averaged across countries using population weights. The sets of poor, emerging, and rich countries are defined as all countries with average PPP converted GDP per capita over the period 1990-2009 within the ranges 0-3,000, 3,000-25,000, and 25,000-∞, respectively. The lists of poor, emerging, and rich countries are presented in the appendix to this chapter. Data source: World Development Indicators.

Fact 1.2 (High Volatility Of Government Consumption) *On average across countries government consumption is twice as volatile as output.*

Investment, exports, and imports are by far the most volatile components of the national income and product accounts, with standard deviations around three times as large as those of output. The trade-balance-to-output ratio and the current-account-to-output ratio are also highly volatile, with standard deviations of more than 2 percent of GDP.

Fact 1.3 (Global Ranking Of Volatilities) *The ranking of cross-country average standard deviations from top to bottom is imports, investment, exports, government spending, consumption, and output.*

We say that a variable is procyclical when it has a positive correlation with output. Table 1.1 reveals that consumption, investment, exports, and imports are all procyclical. Private consumption is the most procyclical component of aggregate demand.

Fact 1.4 (Procyclicality Of The Components of Aggregate Demand) *On average consumption, investment, exports, and imports are all positively correlated with output.*

By contrast, the trade balance, the trade-balance-to-output ratio, the current account, and the current-account-to-output ratio are all countercyclical. This means that countries tend to import more than they export during booms and to export more than they import during recessions.

Fact 1.5 (Countercyclicality Of The Trade Balance And The Current Account) *On average across countries the trade balance, the trade-balance-to-output ratio, the current account, and the current-account-to-output ratio are all negatively correlated with output.*

It is worth noting that the government-spending-to-output ratio is roughly acyclical. This empirical regularity runs contrary to the traditional Keynesian stabilization policy prescription according to which the share of government spending in GDP should be increased during contractions and cut during booms.

Fact 1.6 (Acyclicality Of The Share Of Government Consumption in GDP) *On average across countries, the share of government consumption in output is roughly uncorrelated with output.*

This fact must be qualified along two dimensions. First, here the variable g denotes government consumption of goods. It does not include government investment, which may be more or less procyclical than government consumption. Second, g does not include transfers. To the extent that transfers are countercyclical and directed to households with high propensities to consume—presumably low-income households—total government spending may be more countercyclical than government consumption.

A standard measure of persistence in time series is the first-order serial correlation. Table 1.1 shows that on average across all countries, output is quite persistent, with a serial correlation of 0.71. All components of aggregate demand as well as imports are broadly as persistent as output.

Fact 1.7 (Persistence) *The components of aggregate supply (output and imports) and aggregate demand (consumption, government spending, investment, and exports) are all positively serially correlated.*

Later in this chapter, we will investigate whether output is a persistent stationary variable or a nonstationary variable. This distinction is important for choosing the stochastic processes of shocks driving our theoretical models of the macro economy.

1.3 Business Cycles in Poor, Emerging, and Rich Countries

An important question in macroeconomics is whether business cycles look differently in poor, emerging, and rich economies. For if this was the case, then a model that is successful in explaining business cycles in, say, rich countries, may be less successful in explaining business cycles in emerging or poor countries. One difficulty with characterizing business cycles at different stages of development is that any definition of concepts such as poor, emerging, or rich country is necessarily arbitrary. For this reason, it is particularly important to be as explicit as possible in describing the classification method adopted.

As the measure of development, we use the geometric average of PPP converted GDP per capita in U.S. dollars of 2005 over the period 1990-2009. Loosely speaking, PPP-converted GDP in a given country is the value of all goods and services produced in that country evaluated at U.S. prices. By evaluating production of goods in different countries at the same prices, PPP conversion makes cross-country comparisons more sensible. To illustrate the concept of PPP conversion, suppose that in a given year country X produces 3 hair cuts and 1 ton of grain and that the unit prices of these items inside country X are, 1 and 200 dollars, respectively. Then, the nonconverted measure of GDP is 203 dollars. Suppose, however, that because a hair cut is not a service that can be easily traded internationally, its price is very different in country X and the United States (few people are willing to fly from one country to another just to take advantage of differences in hair cut prices). Specifically, assume that a hair cut costs 20 dollars in the United States, twenty times more than in country X. Assume also that, unlike hair cuts, grain is freely traded internationally, so its price is the same in both countries. Then, the PPP-converted measure of GDP in country X is 260. In this example, the PPP adjusted measure is higher than its unadjusted counterpart, reflecting the fact that nontraded services are more expensive in the United States than in country X.

We define the set of poor countries as all countries with annual PPP-converted GDP per capita of up to 3,000 dollars, the set of emerging countries as all countries with PPP-converted GDP per capita between 3,000 and 25,000 dollars, and the set of rich countries as all countries with PPP-converted GDP per capita above 25,000 dollars. This definition delivers 40 poor countries, 58 emerging countries, and 22 rich countries. The lists of countries in each category appear in the appendix to this chapter. The fact that there are fewer rich countries than either emerging or poor countries makes sense because the distribution of GDP per capita across countries is highly skewed to the right, that is, the world is characterized by few very high-income countries and many low- to medium-income countries. Summary statistics for each income group are population-weighted averages of the corresponding country-specific summary statistics.

Table 1.1 shows that there are significant differences in volatility across income levels. Compared to rich countries, the rest of the world is a roller coaster. A simple inspection of table 1.1 makes it clear that the central difference between business cycles in rich countries and business cycles in either emerging or poor countries is that rich countries are about half as volatile as emerging or poor countries. This is true not only for output, but also for all components of aggregate demand.

Fact 1.8 (Excess Volatility of Poor and Emerging Countries) *Business cycles in rich countries are about half as volatile as business cycles in emerging or poor countries.*

Explaining this impressive fact is perhaps the most important unfinished business in macroeconomics. Are poor and emerging countries more volatile than rich countries because they face more volatile shocks, such as terms of trade, country risk premia, productivity disturbances, or animal spirits? Or is their elevated instability the result of precarious economic institutions, manifested in, for example, poorly designed monetary and fiscal policies, political distortions, fragile financial systems, or weak enforcement of economic contracts, that tend to exacerbate the aggregate effects of changes in fundamentals? One of the objectives of this book is to shed light on these two non-mutually exclusive views.

A second important fact that emerges from the comparison of business-cycle statistics across income levels is that consumption smoothing is increasing with income per capita. In rich countries consumption is 13 percent less volatile than output, whereas in poor countries it is 12 percent more volatile. In emerging countries, consumption and output are about equally volatile.

Fact 1.9 (Less Consumption Smoothing in Poor and Emerging Countries) *The relative consumption volatility is higher in poor and emerging countries than in rich countries.*

Table 1.1 documents two additional important differences between observed business cycles in rich countries and the rest of the world. One is that the trade-balance-to-output ratio is more countercyclical the richer is the country.

Fact 1.10 (The Countercyclicality of the Trade Balance Increases With Income) *The trade-balance-to-output ratio is more negatively correlated with output the higher is the level of economic development.*

This regularity is driven by the fact that the procyclicality of imports is relatively larger in rich countries than in poor or emerging countries. For rich countries, the correlation of imports with output is twice as large as the correlation of exports with output. This ratio falls to 1.5 for emerging countries and to 1 for poor countries.

The second important difference between business cycles in rich countries and the rest of the world that emerges from table 1.1 is that in rich countries the share of government consumption in GDP is significantly more countercyclical than in emerging or poor countries.

Fact 1.11 (The Countercyclicality of Government Spending Increases With Income) *The share of government consumption is countercyclical in rich countries, but acyclical in emerging and poor countries.*

Rich countries appear to deviate less from the classic Keynesian stabilization rule of boosting (reducing) the share of government spending during economic contractions (expansions) than do poor or emerging economies.

1.4 Country Size and Observed Business Cycles

Table 1.2 presents business-cycle facts disaggregated by country size. Countries are sorted into three size categories: small, medium, and large. These three categories are defined, respectively, as all countries with population in 2009 of less than 20 million, between 20 and 80 million, and more than 80 million. The first regularity that emerges from table 1.2 is that conditional on size, rich countries are at least half as volatile as emerging or poor countries. This means that fact 1.8 is robust to controlling for country size. To further characterize the partial correlations of output volatility with economic development and country size, we regress the standard deviation of output per capita of country i, denoted $\sigma_{y,i}$, onto a constant, the logarithm of country i's population in 2009, denoted $\ln \mathrm{pop}_i$, the logarithm of country i's average PPP-converted output per capita over the period 1990-2009, denoted $\ln y_i^{PPP}$, and country i's openness share, denoted xmy_i. All 120 countries in the sample are included. The regression yields

$$\begin{array}{rlllll} \sigma_{y,i} = & 15.0 & -0.08 \ln \mathrm{pop}_i & -0.78 \ln y_i^{PPP} & +0.86\, xmy_i + \epsilon_i \\ t-\mathrm{stat} & (3.5) & (-0.4) & (-2.9) & (0.9) \\ R^2 = & 0.07 & & & \end{array}$$

This regression shows that both higher income per capita and larger country size tend to be associated with lower output volatility. At the same time, more open economies appear to be more volatile. Note, however, that population and openness are statistically insignificant.

Table 1.2 suggests that the consumption-output volatility ratio falls with income per capita and,

Table 1.2: Business Cycles in Small, Medium, and Large Countries

	All Countries			Poor Countries			Emerging Countries			Rich Countries		
	S	M	L	S	M	L	S	M	L	S	M	L
Standard Deviations												
σ_y	8.00	7.92	5.55	8.17	9.46	5.63	9.50	8.99	7.86	4.31	3.05	3.29
σ_c/σ_y	1.12	0.96	1.07	1.39	1.05	1.11	0.97	0.93	1.08	0.92	0.93	0.84
σ_g/σ_y	2.22	2.21	2.28	2.92	2.86	2.40	1.85	2.05	1.99	1.66	1.71	1.76
σ_i/σ_y	3.65	3.23	3.06	4.68	4.01	3.08	2.97	2.86	2.58	3.07	3.07	3.28
σ_x/σ_y	2.46	3.29	3.07	2.81	3.94	3.01	2.23	2.92	2.95	2.23	3.33	3.56
σ_m/σ_y	2.55	3.12	3.33	2.96	3.45	3.30	2.25	2.68	3.02	2.36	3.80	3.77
$\sigma_{tb/y}$	4.29	3.64	1.76	5.62	3.82	1.77	4.00	4.39	2.75	2.29	1.47	0.98
$\sigma_{ca/y}$	3.68	2.97	1.84	4.84	3.40	1.87	3.55	3.45	2.39	2.37	1.47	1.23
Correlations with y												
y	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
c	0.64	0.71	0.69	0.58	0.74	0.66	0.73	0.70	0.84	0.55	0.70	0.82
g/y	-0.03	-0.01	-0.02	0.02	0.24	0.07	0.03	0.00	-0.26	-0.26	-0.40	-0.40
i	0.60	0.70	0.66	0.45	0.55	0.61	0.72	0.76	0.82	0.63	0.74	0.81
x	0.54	0.42	0.08	0.53	0.58	0.08	0.53	0.36	0.25	0.58	0.37	0.00
m	0.59	0.57	0.11	0.53	0.62	0.07	0.62	0.57	0.34	0.63	0.47	0.23
tb/y	-0.12	-0.24	-0.13	-0.04	-0.25	-0.10	-0.21	-0.24	-0.17	-0.11	-0.24	-0.29
tb	-0.21	-0.26	-0.15	-0.18	-0.33	-0.12	-0.32	-0.24	-0.21	-0.04	-0.24	-0.29
ca/y	-0.17	-0.22	-0.30	-0.17	-0.11	-0.30	-0.20	-0.34	-0.11	-0.11	-0.08	-0.44
ca	-0.21	-0.25	-0.30	-0.23	-0.17	-0.29	-0.25	-0.36	-0.13	-0.08	-0.10	-0.43
Serial Correlations												
y	0.83	0.83	0.66	0.76	0.84	0.62	0.89	0.84	0.90	0.83	0.80	0.74
c	0.67	0.69	0.66	0.61	0.61	0.62	0.70	0.71	0.81	0.73	0.75	0.75
g	0.73	0.80	0.75	0.61	0.74	0.72	0.78	0.80	0.81	0.87	0.89	0.90
i	0.66	0.66	0.53	0.62	0.64	0.47	0.67	0.70	0.79	0.71	0.61	0.70
x	0.67	0.75	0.67	0.58	0.73	0.65	0.74	0.76	0.70	0.68	0.75	0.74
m	0.69	0.70	0.63	0.68	0.68	0.60	0.71	0.72	0.80	0.66	0.71	0.68
tb/y	0.54	0.58	0.63	0.50	0.51	0.61	0.52	0.58	0.74	0.67	0.68	0.70
ca/y	0.42	0.50	0.60	0.36	0.42	0.57	0.40	0.46	0.65	0.56	0.67	0.75
Means												
tby	-5.6	-1.5	-0.8	-10.4	-5.4	-0.7	-5.2	-0.0	-1.7	3.1	0.0	-0.6
xmy	73.9	48.6	29.0	57.7	48.9	29.5	69.2	49.7	29.9	116.8	45.2	25.3

Note. See table 1.1. The sets of small (S), medium (M), and large (L) countries are defined as countries with 2011 populations of, respectively, less than 20 million, between 20 and 80 million, and more than 80 million.

less strongly, also with country size. This relationship is corroborated by the following regression:

$$\begin{array}{llllll} \ln\left(\frac{\sigma_{c,i}}{\sigma_{y,i}}\right) = & 1.8 & -0.06 \ln \text{pop}_i & -0.11 \ln y_i^{PPP} & +0.14\, xmy_i + \epsilon_i \\ t-\text{stat} & (4.1) & (-2.7) & (-3.8) & (+1.4) \\ R^2 = & 0.19 & & & \end{array}$$

According to this regression, more populous and richer countries tend to have a lower relative volatility of consumption. Taking into account that the volatility of output falls with size and income, this means that the volatility of consumption falls even faster than that of income as size and income increase. These results generalize fact 1.9, according to which consumption smoothing increases with income.

Finally, table 1.2 shows that smaller countries are more open than larger countries. This result holds unconditionally as well as conditional upon the level of income.

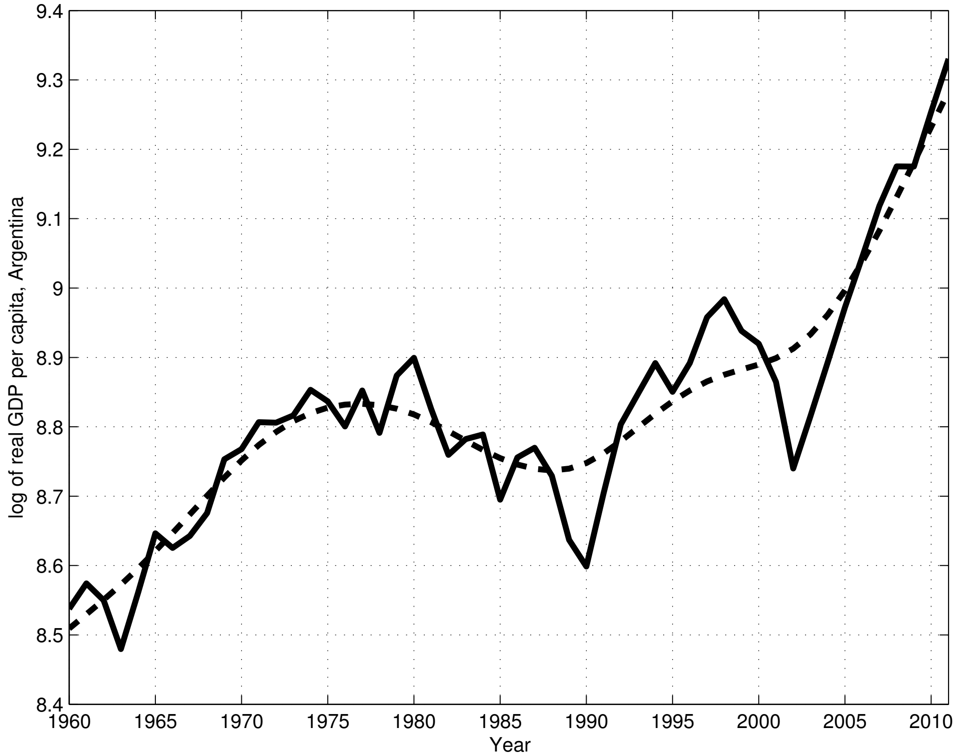
1.5 Hodrick-Prescott Filtering

We now consider an alternative detrending method developed by Hodrick and Prescott (1997), known as the Hodrick-Prescott, or HP, filter. The HP filter identifies the cyclical component, y_t^c, and the trend component, y_t^s, of a given series y_t , for $t = 1, 2, \ldots T$, as the solution to the minimization problem

$$\min_{\{y_t^c, y_t^s\}_{t=1}^T} \left\{ \sum_{t=1}^{T} (y_t^c)^2 + \lambda \sum_{t=2}^{T-1} \left[(y_{t+1}^s - y_t^s) - (y_t^s - y_{t-1}^s) \right]^2 \right\} \tag{1.2}$$

subject to (1.1). The appendix provides the first-order conditions and solution to this problem. According to this formula, the HP trend is the result of a trade off between minimizing the variance of the cyclical component and keeping the growth rate of the trend constant. This tradeoff is

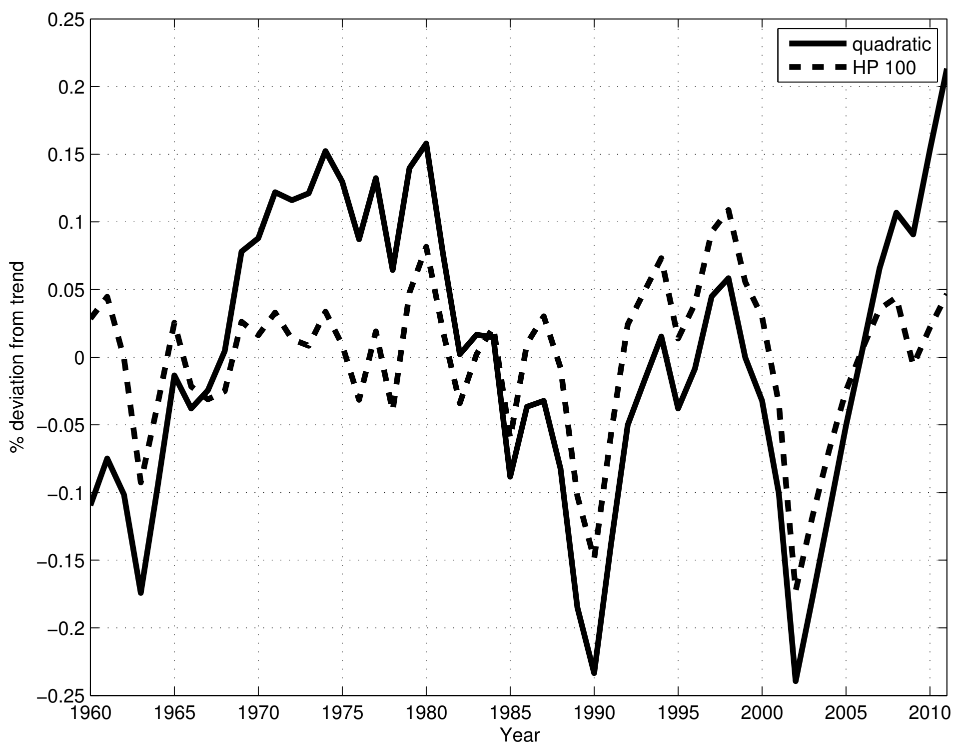
Figure 1.2: HP Filtered Trend of Argentine Output ($\lambda = 100$)



governed by the parameter λ. The larger is λ the more penalized are changes in the growth rate of the trend. In the limit as λ goes to infinity, the trend component associated with the HP filter coincides with the linear trend. At the other extreme, as λ goes to zero, all of the variation in the time series is attributed to the trend and the cyclical component is nil.

Business-cycle studies that use data sampled at an annual frequency typically assume a value of λ of 100. Figure 1.2 displays the trend in Argentine real per capita GDP implied by the HP filter for λ equal to 100. The HP filter attributes a significant fraction of the output decline during the lost decade (1980-1989) to the trend. By contrast, the log-quadratic trend is monotonically increasing during this period, implying that the lost decade was a cyclical phenomenon. Figure 1.3 displays the cyclical component of Argentine output according to the HP filter ($\lambda = 100$) and the

Figure 1.3: Cyclical Component of Argentine GDP HP Filter 100 Versus Quadratic Trend



log-quadratic filter. The correlation between the two cyclical components is 0.70, indicating that for the most part they identify the same cyclical movements. However, the two filters imply quite different amplitudes for the Argentine cycle. The standard deviation of the cyclical component of output is 10.8 percent according to the log-quadratic filter, but only 5.7 percent according to the HP filter. The reason for this large reduction in the volatility of the cycle when applying the HP filter is that under this filter the trend moves much more closely with the raw series.

The value of λ plays an important role in determining the amplitude of the business cycle implied by the HP filter. Recently, Ravn and Uhlig (2001) have suggested a value of λ of 6.25 for annual data. Under this calibration, the standard deviation of the cyclical component of Argentine GDP drops significantly to 3.6 percent. Figure 1.4 displays the actual Argentine GDP and the trend implied by the HP filter when λ takes the value 6.25. In this case, the trend moves much closer with the actual series. In particular, the HP filter now attributes the bulk of the 1989 crisis and much of the 2001 crisis to the trend. This is problematic, especially for the 2001 depression. For this was a V-shaped, relatively short contraction followed by a swift recovery. This suggest that the 2001 crisis was a business-cycle phenomenon. By contrast, the HP trend displays a significant contraction in 2001, suggesting that the crisis was to a large extent noncyclical. For this reason, we calibrate λ at 100 for the subsequent analysis.

Table 1.3 displays business-cycle statistics implied by the HP filter for $\lambda = 100$. The central difference between the business-cycle facts derived from quadratic detrending and HP filtering is that under the latter detrending method the volatility of all variables falls by about a third. In particular, the average cross-country standard deviation of output falls from 6.2 percent under quadratic detrending to 3.8 percent under HP filtering.

In all other respects, the two filters produce very similar business-cycle facts. In particular, facts 1.1-1.11 are robust to applying the HP filter with $\lambda = 100$.

Figure 1.4: Trend of Argentine Output According to the HP Filter 6.25

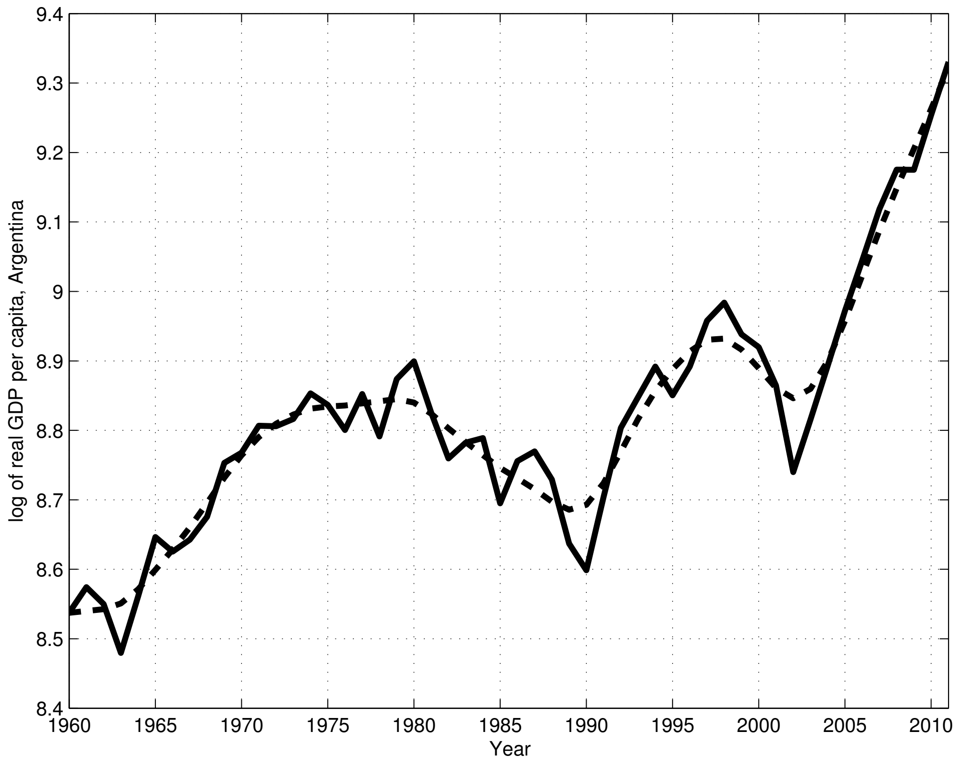


Table 1.3: HP-Filtered Business Cycles

Statistic	All Countries	Poor Countries	Emerging Countries	Rich Countries
Standard Deviations				
σ_y	3.79	4.12	3.98	2.07
σ_c/σ_y	1.08	1.09	1.23	0.87
σ_g/σ_y	2.29	2.53	2.29	1.23
σ_i/σ_y	3.77	3.80	3.79	3.62
σ_x/σ_y	3.50	3.47	3.67	3.42
σ_m/σ_y	3.65	3.70	3.52	3.63
$\sigma_{tb/y}$	1.79	1.64	2.92	0.89
$\sigma_{ca/y}$	1.78	1.71	2.63	1.02
Correlations with y				
y	1.00	1.00	1.00	1.00
c	0.60	0.53	0.68	0.82
g/y	-0.08	0.02	-0.06	-0.56
i	0.69	0.65	0.71	0.86
x	0.19	0.18	0.13	0.30
m	0.32	0.23	0.46	0.58
tb/y	-0.18	-0.08	-0.34	-0.37
tb	-0.20	-0.11	-0.36	-0.36
ca/y	-0.32	-0.29	-0.39	-0.38
ca	-0.33	-0.29	-0.41	-0.37
Serial Correlations				
y	0.46	0.39	0.60	0.55
c	0.36	0.29	0.44	0.53
g	0.51	0.48	0.52	0.65
i	0.34	0.27	0.45	0.46
x	0.47	0.47	0.44	0.46
m	0.42	0.43	0.44	0.33
tb/y	0.39	0.36	0.42	0.47
ca/y	0.39	0.36	0.39	0.54
Means				
tb/y	-1.3	-1.6	-1.4	-0.0
$(x+m)/y$	36.5	32.5	46.4	40.4

Note. See table 1.1. The variables y, c, g, i, x, and m are HP filtered in logs and expressed in percent deviations from trend, and the variables tb/y and ca/y are HP filtered in levels and expressed in percentage points of output. The variables tb and ca were scaled by the secular component of GDP and then HP-filtered. The parameter λ of the HP filter takes the value 100.

Table 1.4: ADF and KPSS Tests for Output in Poor, Emerging, and Rich Countries

Lags	All Countries	Poor Countries	Emerging Countries	Rich Countries
ADF Test				
0	0.5	0.7	0.1	0.3
1	0.3	0.3	0.0	0.3
2	0.3	0.4	0.0	0.3
3	0.2	0.3	0.0	0.1
AIC for Lag Length	0.8	0.9	1.0	0.5
KPSS Test				
0	1.0	1.0	1.0	1.0
1	1.0	1.0	0.9	0.9
2	1.0	1.0	0.9	0.9
3	0.9	0.9	0.8	0.9
AIC for Lag Length	0.0	0.0	0.0	0.0

Note. See notes to table 1.1. Entries correspond to population-weighted decision values for the ADF and KPSS tests. For each country, a decision value of 1 indicates rejection of the null at 5% confidence level and a decision value of 0 indicates failure to reject the null. The null hypothesis is unit root under the ADF test and all roots within the unit circle in the KPSS test. Decision values are based on an F test. AIC stands for the population weighted cross-country average of the lag length suggested by the Akaike information criterion.

1.6 Growth Rates

Thus far, we have detrended output and all other components of aggregate demand using either a log-quadratic trend or the HP filter. An alternative to these two approaches is to assume that NIPA variables have a stochastic trend. Here, we explore this avenue. Specifically, we assume that the levels of the variables of interest are nonstationary, but that their growth rates are. That is, we assume that the logarithm of output and other NIPA components are integrated of order one.

Table 1.4 displays two statistical tests that provide evidence in favor of modeling NIPA data around the world as stationary in growth rates and nonstationary in levels. The top panel of the table displays the results of applying the ADF test to the logarithm of real per capita GDP. The ADF test evaluates the null hypothesis that a univariate representation of the time series in question has a unit root against the alternative hypothesis that it does not. The table displays population-weighted cross-country averages of the decision value. The decision value is unity if the null hypothesis is rejected and 0 if it cannot be rejected. The table shows that the null hypothesis is rejected in 30 percent of the countries at the lag length of 1 year suggested by the Akaike information criterion (AIC), providing support to the unit-root hypothesis.

The lower panel of table 1.4 displays the results of applying the KPSS test to the logarithm of real output. This test evaluates the null hypothesis that the univariate representation of the logarithm of output has no unit root versus the alternative hypothesis that it does. For the lag length favored by the AIC test, the decision value is unity for virtually all countries, which suggests that the hypothesis of stationarity in levels is strongly rejected.

The results of the ADF and KPSS tests have to be interpreted with caution. The reason is that they both are based on the assumption that the time series in question has a univariate representation. As we will see in the following chapters, in general, theoretical models of the business cycle do not imply that output has a univariate representation.

Table 1.5 displays standard deviations, correlations with output growth, and serial correlations of the growth rates of output, consumption, government consumption, investment, exports, and imports. Most of the business-cycle facts obtained under quadratic detrending also hold true when stationarity is induced by first-differencing the data. We stress the three key regularities identified earlier: World business cycles are highly volatile (fact 1.1). The cross-country average volatility of output growth is twice as large as the volatility of U.S. output growth (not shown). Poor and emerging countries are twice as volatile as rich countries (fact 1.8). The volatility of consumption growth relative to output growth is much higher in emerging and poor countries than in rich countries (fact 1.9). The trade-balance share is negatively correlated with output growth (fact 1.5).

Table 1.5: First Differenced Business Cycles

Statistic	All Countries	Poor Countries	Emerging Countries	Rich Countries
Standard Deviations				
$\sigma_{\Delta y}$	4.39	4.94	4.08	2.38
$\sigma_{\Delta c}/\sigma_{\Delta y}$	1.14	1.14	1.34	0.85
$\sigma_{\Delta g}/\sigma_{\Delta y}$	2.14	2.28	2.39	1.17
$\sigma_{\Delta i}/\sigma_{\Delta y}$	3.81	3.80	4.06	3.49
$\sigma_{\Delta x}/\sigma_{\Delta y}$	3.37	3.22	3.98	3.22
$\sigma_{\Delta m}/\sigma_{\Delta y}$	3.60	3.50	3.84	3.76
$\sigma_{tb/y}$	2.34	2.12	3.80	1.25
$\sigma_{ca/y}$	2.16	2.06	3.08	1.39
Correlations with Δy				
Δy	1.00	1.00	1.00	1.00
Δc	0.60	0.54	0.64	0.79
g/y	-0.10	-0.02	-0.18	-0.32
Δi	0.64	0.59	0.66	0.83
Δx	0.21	0.18	0.15	0.42
Δm	0.33	0.26	0.40	0.57
tb/y	-0.10	-0.08	-0.20	-0.07
ca/y	-0.07	-0.06	-0.12	-0.07
Serial Correlations				
Δy	0.29	0.28	0.29	0.32
Δc	0.02	-0.03	0.02	0.27
Δg	0.18	0.14	0.11	0.48
Δi	0.01	-0.01	0.03	0.08
Δx	0.07	0.08	-0.00	0.10
Δm	0.04	0.08	-0.02	-0.04
tb/y	0.61	0.59	0.62	0.69
ca/y	0.57	0.55	0.52	0.71

Note. See notes to table 1.1. The variables Δy, Δc, Δg, Δi, Δx, and Δm denote, respectively the log differences of output, consumption, government consumption, investment, exports, and imports. The variables g/y, tb/y, and ca/y are quadratically detrended in levels. All variables are expressed in percent.

Finally, we note that, predictably, the serial correlations of growth rates are much lower than their (detrended) level counterparts.

1.7 Duration and Amplitude of Business Cycles in Emerging and Developed Countries

We have documented that emerging countries display significantly more output volatility than developed countries. We now decompose business cycles into contractions and expansions and estimate for each of these phases of the cycle its duration and magnitude. Calderón and Fuentes (2010) adopt a classical approach to characterizing business cycles in emerging and developed countries, consisting in identifying peaks and troughs in the logarithm of real quarterly GDP. They define a peak as an output observation that is larger than the two immediately preceding and succeeding observations. Formally, letting y_t denote the logarithm of real GDP, a peak takes place when $y_t > y_{t+j}$, for $j = -2, -1, 1, 2$. Similarly, a trough is defined as an output observation that is lower than its two immediately preceding and succeeding observations, or a level of y_t satisfying $y_t < y_{t+j}$, for $j = -2, -1, 1, 2$. The duration of a cycle is the period of time that goes from one peak to the next. The duration of a contraction is the period of time that goes from a peak to the next trough. And the duration of an expansion is the period of time that goes from a trough to the next peak. The amplitude of a contraction is the percentage fall in output between a peak and the next trough. The amplitude of an expansion is the percentage increase in output between a trough and the next peak.

Table 1.6 displays the average duration and amplitude of business cycles in two groups of countries, one consisting of 12 Latin America countries and the other of 12 OECD countries. We will identify the former group with emerging countries and the latter with developed countries. The table shows that contractions are on average quite short (about 11 months) and of about the same

Table 1.6: Duration and Amplitude of Business Cycles in Emerging and Developed Economies

Group of	Duration		Amplitude	
Countries	Contraction	Expansion	Contraction	Expansion
Latin America	3.5	16.0	6.2	21.3
OECD	3.6	23.8	2.2	20.2

Source: Calderón and Fuentes (2010).
Note: The data is quarterly real GDP from 1980:1 to 2006:4. The countries included in the Latin America group are: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Paraguay, Peru, Uruguay, and Venezuela. The countries included in the OECD group are Australia, Canada, France, Germany, Italy, Japan, New Zealand, Portugal, Spain, Sweden, United Kingdom, and the United States.

duration in emerging and developed countries. However, contractions are much more pronounced in emerging countries than in developed countries (6.2 versus 2.2 percent of GDP). At the same time, expansions are much longer than contractions, and are shorter in emerging countries than in developed countries (16 versus 23.8 quarters). However, the amplitude of expansions is about the same in both groups of countries (about 20 percent of GDP). Finally, emerging countries are more cyclical than developed countries in the sense that the former complete cycles are shorter (20 quarters versus 27 quarters, which results from adding the average durations of contractions and expansions). The general pattern that emerges is of emerging countries being more volatile because they display more cycles per unit of time and experience more pronounced contractions on average.

1.8 Appendix

1.8.1 Countries Included In The Sample

The sample consists of 120 countries. There are 22 small poor countries, 11 medium-size poor countries, 7 large poor countries, 41 small emerging countries, 14 medium-size emerging countries, 3 large emerging countries, 14 small rich countries, 5 medium-size rich countries and 3 large rich countries. The individual countries belonging to each group are listed below.

Small Poor Countries: Benin, Bhutan, Burkina Faso, Burundi, Central African Republic, Comoros, Gambia, Guyana, Honduras, Lesotho, Malawi, Mali, Mauritania, Mongolia, Niger, Papua New Guinea, Rwanda, Senegal, Sierra Leone, Togo, Zambia, Zimbabwe.

Medium Size Poor Countries: Cameroon, Congo, Dem. Rep., Cote d'Ivoire, Ghana, Kenya, Madagascar, Mozambique, Nepal, Sri Lanka, Sudan, Uganda.

Large Poor Countries: Bangladesh, China, Ethiopia, India, Indonesia, Pakistan, Philippines.

Small Emerging Countries: Albania, Antigua and Barbuda, Bahrain, Barbados, Bolivia, Botswana, Bulgaria, Chile, Costa Rica, Cuba, Cyprus, Dominica, Dominican Republic, Ecuador, El Salvador, Fiji, Gabon, Greece, Grenada, Guatemala, Hungary, Israel, Jordan, Malta, Mauritius, Namibia, New Zealand, Panama, Paraguay, Portugal, Puerto Rico, Seychelles, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Swaziland, Tonga, Trinidad and Tobago, Tunisia, Uruguay.

Medium Size Emerging Countries: Algeria, Argentina, Colombia, Iran, South Korea, Malaysia, Morocco, Peru, South Africa, Spain, Syria, Thailand, Turkey, Venezuela.

Large Emerging Countries: Brazil, Egypt, Mexico.

Small Rich Countries: Austria, Belgium, Denmark, Finland, Hong Kong, Iceland, Ireland, Luxembourg, Macao, Netherlands, Norway, Singapore, Sweden, Switzerland.

Medium Size Rich Countries: Australia, Canada, France, Italy, United Kingdom.

Large Rich Countries: Germany, Japan, United States.

1.8.2 Derivation of the HP Filter

The first-order conditions associated with the problem of choosing the series $\{y_t^c, y_t^s\}_{t=1}^T$ to minimize (1.2) subject to (1.1) are

$$y_1 = y_1^s + \lambda(y_1^s - y_2^s + y_s^3),$$

$$y_2 = y_2^s + \lambda(-2y_1^s + 5y_2^s - 4y_3^s + y_4^s),$$

$$y_t = y_t^s + \lambda(y_{t-2}^s - 4y_{t-1}^s + 6y_t^s - 4y_{t+1}^s + y_{t+2}^s); \quad t = 3, \ldots, T-2,$$

$$y_{T-1} = y_{T-1}^s + \lambda(y_{T-3}^s - 4y_{T-2}^s + 5y_{T-1}^s - 2y_T^s),$$

and

$$y_T = y_T^s + \lambda(y_{T-2}^s - 2y_{T-1}^s + y_T^s).$$

Letting $Y^s \equiv [y_1^s\, y_2^s\, \ldots y_T^s]$ and $Y \equiv [y_1\, y_2\, \ldots y_T]$, the above optimality conditions can be written in matrix form as

$$Y = (I + \lambda A)Y^s,$$

where I is the $T \times T$ identity matrix. and A is the following $T \times T$ matrix of constants

$$A = \begin{bmatrix} 1 & -2 & 1 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\ -2 & 5 & -4 & 1 & 0 & 0 & 0 & 0 & \dots & 0 \\ 1 & -4 & 6 & -4 & 1 & 0 & 0 & 0 & \dots & 0 \\ 0 & 1 & -4 & 6 & -4 & 1 & 0 & 0 & \dots & 0 \\ 0 & 0 & 1 & -4 & 6 & -4 & 1 & 0 & \dots & 0 \\ \vdots & & & & & & & & & \vdots \\ 0 & \dots & 0 & 1 & -4 & 6 & -4 & 1 & 0 & 0 \\ 0 & \dots & 0 & 0 & 1 & -4 & 6 & -4 & 1 & 0 \\ 0 & \dots & 0 & 0 & 0 & 1 & -4 & 6 & -4 & 1 \\ 0 & \dots & 0 & 0 & 0 & 0 & 1 & -4 & 5 & -2 \\ 0 & \dots & 0 & 0 & 0 & 0 & 0 & 1 & -2 & 1 \end{bmatrix}.$$

Solving for Y^s, one obtains:

$$Y^s = (I + \lambda A)^{-1} Y.$$

Finally, letting $Y^c \equiv [y_1^c \, y_2^c \, \dots y_T^c]$ we have that

$$Y^c = Y - Y^s.$$