Seminar Paper No. 473

SWEDISH BUSINESS CYCLES: 1861-1988

by

Peter Englund, Torsten Persson and Lars E.O. Svensson

Seminar Papers are preliminary material circulated to stimulate discussion and critical comment.

August 1990

Institute for International Economic Studies
S-106 91 Stockholm
Sweden
SWEDISH BUSINESS CYCLES:
1861–1988

Peter Englund
Department of Economics, Uppsala University

Torsten Persson
Institute for International Economic Studies

Lars E. O. Svensson
Institute for International Economic Studies

First draft: May, 1990
This version: September, 1990

* We thank participants of the workshop "The Swedish Business Cycle" and seminar participants at IIES for their comments, John Hassler for expert research assistance, Cindy Miller for editorial and secretarial assistance, and the Bank of Sweden Tercentenary Foundation, as well as the Social Science Research Council, for financial support.
1. Introduction

Recent empirical studies of business cycles have focused on establishing robust stylized facts. Such stylized facts are typically based on detrended time series for major economic aggregates, and are presented in the form of variances and autocorrelations of the different series and contemporaneous and lagged correlation coefficients between a reference series (typically GDP) and other series.

This study aims at presenting corresponding stylized facts for the Swedish business cycle. It uses data from 1861 to 1988. The scope of the database may well be unique in an international comparison; it includes not only GDP and its components, but also labor market variables like employment and wages. The quality of the data base can be considered high by international standards. We present the sources for these data in section 2 of the paper.

In contrast to many other studies, we focus specifically on the business cycle, by which we mean cyclical comovements between macroeconomic variables with periods of around 5 years. Defining the business cycle by frequency of fluctuations, it becomes natural to exploit spectral analysis. In section 3 we look at spectra of series which first have been detrended according to two methods: first-differencing and the Hodrick-Prescott filter. We find a considerable amount of spectral mass for periods of between 3 and 8 years, which we interpret as evidence of a business cycle in our data.

Since our aim is to look at the stylized facts of the business cycles rather than of the time series in general, it is natural to treat the data in such a way so that all variation outside business cycle frequencies is filtered out. To do that we use a so-called band-pass filter. The filter is described in section 4, where we also compare the resulting filtered business-cycle series with the original detrended series.

Our results based on the filtered data are presented in the last two sections of the
paper. In section 5 we report stylized facts based on the whole period. Overall, they are pretty conventional. GDP and consumption show the lowest standard deviation, whereas investment, exports and imports show the highest standard deviation. Most correlation coefficients with GDP are positive. GDP is contemporaneously uncorrelated with wages and productivity, but positively correlated with GDP lagged one year.

Lucas (1977) advanced the hypothesis that business cycles are "all alike". To investigate this issue we look in section 6 at the stability of our stylized facts over time. We do this by computing all statistics for moving 41-year periods from 1861–1901 to 1948–1988. The results are striking. First, the variance of most series increases, from the pre-war towards the inter-war period, and then it decreases again towards the post-war period. Nevertheless, the relative variances of the different series remain remarkably stable. This is the case in particular when comparing the inter-war and post-war periods. Indeed, the ratio between the standard deviations for the 41 years centered on 1930 and 1968, respectively, is very close to 2 for all variables. Likewise, most correlation coefficients remain stable across subperiods. In this sense the Swedish business cycle seems to be uniform ("all alike") across seemingly very different epochs of Swedish economic history.

2. Data

Our purpose is to establish stylized facts of the Swedish business cycle using data beginning with the 1860's. We limit ourselves to looking at the main real variables without including any nominal magnitudes. More specifically, our study covers the items on the destination account of the national accounts, and production, employment and wages in the manufacturing sector of the Swedish economy, i.e. the following series which are depicted in logarithms in Figure 1: gross domestic product (GDP), manufacturing
production \( (Q) \), private consumption \( (C) \), investment \( (I) \), exports \( (X) \), imports \( (M) \), employment \( (L) \), wages \( (W) \), and productivity \( (Q/P) \). See Appendix 1 for the details of definitions and sources.

The basic data sources that we use stem from a major project undertaken in the 1930's at the Institute for Social Sciences at the University of Stockholm covering the period from 1860 to 1930, the results of which were published in Myrdal (1933), in Bagge, Lundberg and Svennilson (1933, 1935) and in E. Lindahl, Dahlgren and Kock (1937). Dahlgren (1936, 1941) and O. Lindahl (1956) subsequently updated the national accounts data. Johansson (1967) presented consistent time series for the period 1861–1955. In 1950 the National Institute of Economic Research (konjunkturinstitutet) started publishing a modern national accounts series. Statistics Sweden later took over the responsibility for the national accounts.

The historical national accounts were originally given in current prices. Conversion to fixed prices could only be done by the cost of living index from Myrdal (1933). Johansson (1967) computed fixed-price series for various sub-aggregates, but still used a cost of living index to deflate GDP to fixed prices. More recently Krantz and Nilsson (1975) extended Johansson's work considerably and constructed price indices for the various components of GDP. They also used these price indices to construct a consistent GDP series at fixed prices from 1861 to 1970.

Our study uses national accounts data from Krantz and Nilsson linked in 1950 with the modern national accounts. We wish to emphasize two problems in this context. The first concerns the treatment of inventory investments. The original historical data are basically constructed from the production side. In particular, they contain no information on inventories. In order to construct series for investment and consumption, the various production sectors are classified as producers of consumption goods, investment goods and/or intermediary goods. Aggregate consumption and investment is then simply total production of consumption and investment goods minus the balance of
trade in those goods. This means that inventory investments are split in unknown proportions between the series for consumption and investment. The modern national accounts from 1950, on the other hand, include inventory investments as a separate item. This means that there is a problem in linking the consumption and investment series. Note, however, that the GDP aggregate consistently includes inventories before as well as after 1950. Absent any particular information on where inventory investments are hidden before 1950 we simply splice all series in 1950.¹

The second problem is that the Krantz and Nilsson fixed-price series apply to GDP at factor cost, whereas the official national accounts only give GDP at market value in fixed prices. We handle this by deflating GDP at factor cost in current prices post 1950 by the implicit GDP deflator for GDP at market value. Given the relatively small share of indirect taxes in GDP, the resulting error is small.²

From the national accounts we take data for gross domestic product, value added in manufacturing and mining, private consumption, investment, exports and imports. With the exception of imports we deflate all series by the implicit GDP deflator, while we use the import price index to deflate imports.

The basic source for historical data on wages is Bagge et al. (1933, 1935). We use

¹ Note that this procedure differs from that used by Krantz and Nilsson in their linking of pre- and post-1950 data. They "start the linking on the destination side of the national product. There it is carried out for the consumption of goods and services, respectively, public consumption and in addition, the investment categories for machinery and buildings, respectively. These items are subsequently aggregated to form sub—totals for consumption and investment and a total for national product." (p. 38). This means that pre—1950 items which sum to GDP are linked with post—1950 items which do not sum to GDP.

² The way one handles both of these problems is of some quantitative importance. For the period 1950—1970 the Krantz and Nilsson data (table 3.1) show an average growth rate of 3.37 per cent (with a standard deviation of 2.12 per cent). For the national accounts at market value in fixed 1968 prices the corresponding figures are 3.77 (1.55), and for our constructed series at factor cost 3.63 (1.42). We see that the Krantz and Nilsson procedure which pretends that there are no inventory investments leads to a considerable underestimation of the variability of GDP. The difference between the market value and factor cost series are minor for this period.

For the period 1970—1987 the official national accounts at fixed market values show an average growth of 2.00 per cent with standard deviation 1.46. Our series at factor cost show a slightly lower growth rate of 1.93 per cent but a considerably higher standard deviation of 1.96.
hourly earnings for workers in manufacturing taken from this source and link it in 1920 with modern data from the Statistics Sweden. We transform this series to real wages by deflating with the implicit deflator for manufacturing production. Employment is measured by total hours worked in manufacturing. We construct this series by dividing the total wage bill to workers in manufacturing taken from Jungenfelt (1966) by our series for hourly earnings. Jungenfelt constructed the wage data by multiplying total number of employed in manufacturing by average yearly earnings. Employment data are from censuses while earnings are from Bagge et al. Finally, our series for productivity is value added in manufacturing over employment.

3. Spectral Analysis

We choose to define business cycles as cyclical comovements of important macroeconomic variables with periods of around 5 years. In this section we use spectral analysis to examine the pattern of Swedish business cycles, i.e. patterns in our time series with periods of around 5 years (see for instance Koopmans (1974), Priestley (1981) or Sargent (1987) for a description of spectral analysis).

Using a Fourier transform, one can express a stationary time series as a sum of cyclical components of different frequencies. This yields the spectrum of the time series which decomposes the series’s total variance into variance attributed to different frequencies. One can interpret the spectrum as a density function. The area under the spectrum for an interval between two frequencies equals the proportion of total variance attributed to components with frequencies within that interval. We are particularly interested in the part of the spectra that corresponds to cyclical components with periods of around 5 years, since the density at these frequencies indicates the relative importance of business cycle fluctuations.
We will also consider the coherence between the GDP series and each of the other series. The coherence between two series at a particular frequency may be interpreted as a correlation coefficient between the two series' cyclical components of that frequency. Coherence squared for a given frequency is the proportion of either series's total variance at that frequency that can be explained by linear regression of one series on the other. Again we are particularly interested in the coherence between GDP and the other series at business cycle frequencies, i.e., for periods of around 5 years.

It is not meaningful to consider spectra and coherences for series that are not stationary. When deciding how to detrend the data, one should ideally rely either on a particular theoretical model, or on statistical tests. Given that we do not have a particular theoretical model in mind, and given the weak power of most tests for stochastic versus deterministic trends, we prefer to take an agnostic view towards detrending. Therefore we transform the raw series into stationary series in two different ways.

One way is to use the filter previously used by Hodrick and Prescott (1980) and others, which is known as the Whittaker–Henderson type A filter. To apply it one chooses a smoothing coefficient $\lambda$. The value of this coefficient reflects the relative variance of the "growth component," which is filtered out from the data, and the remaining stationary component. In our study we choose $\lambda = 400$, which is lower than the value of 1600 used in several studies of quarterly data. Our motivation is that the relative variability of the growth component should be expected to be larger in annual than in quarterly data; results are not sensitive to the value of $\lambda$ though.

The other way of taking the trend out of the data is to take first differences. We apply both detrending methods to the logs of each series. Given that we are interested in establishing robust stylized facts and given the well-known difficulties in judging a priori what kind of trend governs macroeconomic time series, we report results from both ways of detrending our raw time series. We have also looked at a third method of detrending,
namely just removing a linear time trend; the results of the spectral analysis in this case
are similar to those reported below (except at the very lowest frequencies where it has
more mass). To shorten the following presentation, let us introduce the label "\( \lambda \)-series"
for those series detrended by applying the Hodrick-Prescott filter and the label
"\( \Delta \)-series" for the series detrended by taking first differences.

The spectra (in logs) and coherences are shown in Figures 2a and 2b for the
\( \lambda \)-series and in Figures 3a and 3b for the \( \Delta \)-series. We plot the spectra and coherences
as functions of frequency, from 1 cycle per the whole period of 128 years (127 years for
first-differenced time series) up to 64 cycles per the whole period. This corresponds to
periods of 128 years down to 2 years. We have previously talked about the business cycle
as fluctuations with "periods of around 5 years." We now operationally define this to
mean *periods of between 3 and 8 years*. A period of 8 years corresponds to a frequency of
16 cycles per whole period, and a period of 3 years corresponds to a frequency of about 43
cycles per whole period.\(^3\) The interval between 3 and 8 years is marked by vertical lines
in the spectra and coherences (the line corresponding to 8 years is the left one, since the
period (frequency) is decreasing (increasing) to the right.

Let us first look at the spectra in Figure 2a, for the \( \lambda \)-series. We see that a fair
amount of the spectral mass for all the series is to the left of the 8-year-period line. That
is, a fair amount of the variation in the series is attributed to components of periods
longer than 8 years. In fact the spectra of all \( \lambda \)-series have a peak at low frequencies,
typically corresponding to a period of 10-12 years. This is what Granger (1966) found to
be the typical spectral shape of economic variables. We also see that there is indeed a
fair amount of spectral mass in most series for periods in the interval between 3 and 8
years.

With regard to the coherences in Figure 2b, we note that there is relatively high

\(^3\) Alternatively, one can measure frequency as cycles per year, so that frequency runs from
1/128 up to 0.5.
coherence between GDP and most series for periods longer than 8 years. There is also fairly high coherence between GDP and several series for periods of between 3 and 8 years. It is only for private consumption that the coherence is high for all business cycle frequencies. For the other series the coherence varies somewhat irregularly with the frequency.

Let us look next at the spectra in Figure 3a for the $\Delta$-series. First-differencing suppresses cyclical components of longer periods. Consequently, we see that compared to the spectra in Figure 2a, there is less spectral mass for periods longer than 8 years and relatively more spectral mass for periods in the interval between 3 and 8 years. The coherences for the $\Delta$-series in Figure 3b look rather similar to the coherences for the $\lambda$-series in Figure 2b.

As an alternative reference series to GDP we have also considered manufacturing production. We note that the coherence between manufacturing production and GDP at business cycle frequencies is quite low except for a narrow band around 5 years. Hence, one would expect a rather different pattern of coherences with the other series. It turns out that the coherences between manufacturing production and the other series are relatively low except for a period of around 10–12 years. No clear pattern arises for shorter periods. The lack of a consistent pattern may be natural in view of the sharp relative increase in the size of the manufacturing sector over the period. In what follows we only report results with GDP as the reference series.

4. Filtering

There are at least two reasons why one may want to eliminate a trend from a macroeconomic time series. One reason is technical: one wants to carry out statistical operations—such as the spectral analysis of Section 3—which require a stationary series.
In the following, we refer to this as *detrending*. The other reason is conceptual: one wants to separate the series into a "growth part" and a "cyclical part." In the following, we refer to this as *filtering*. As we noted in Section 3 we are agnostic about the proper way of detrending and we report results for different methods —both for the $\lambda$-series and for the $\Delta$-series, as defined above—and look for results that seem robust relative to the method of detrending.

On the other hand, when deciding how to filter, one cannot escape an a priori judgment: to study business cycle fluctuations, it is necessary to be clear about what one means by business cycles. We have already declared that we subscribe to a traditional view of business cycles, namely "cyclical comovements of important macro variables with a period of around 5 years." And we want to choose a filter that corresponds as closely as possible to this view.

For our purposes it is therefore natural to use a filter that operates in the frequency domain, rather than in the time domain. We will use a band-pass filter (see Priestley (1981) p. 274–5). It works roughly like this: (1) transform a given detrended time series to the frequency domain by the Fourier transform, (2) filter out all the components, except for those in a particular frequency band, and (3) transform the remaining components back to the time domain by the inverse Fourier transform. The result of these three operations is our measure of the cyclical part of the series. *Appendix 2* gives a formal definition of our filter, and discusses some technical issues.

In line with our previous discussion we choose a band between 3 and 8 years, i.e. we shut out completely all frequencies corresponding to cycles below 3 and above 8 years. We have experimented with moving the boundaries of our frequency band in each direction, but this does not produce any major changes in the results.

Qualitatively, filtering has a similar effect for all time series. *Figure 4* illustrates the effects of applying our filter to a few selected time series: the $\lambda$-series for GDP, exports and hours and the $\Delta$-series for GDP. A first effect is that filtering reduces the
fluctuations in all four series. This is obvious, since we are filtering out frequency components that are associated with significant spectral mass. A second effect is that filtering induces a more regular cyclical pattern. This is also an obvious, and desired, result. Counting the number of peaks and troughs, we end up with close to 25 cycles over 128 (127) years, which corresponds well to our notion of business cycles having a period of around 5 years. A third effect is that filtering greatly reduces certain outliers, particularly during the interwar period. While it is less obvious, this effect is nevertheless understandable. Looking at the detrended series in Figure 4, we see that the sequence of extreme observations in the interwar period actually looks like a cycle with a period of 10 to 12 years. These outliers are thus a likely explanation for the peaks in the spectra for relatively low frequencies that we noted in Section 3. Our filter eliminates fluctuations at these frequencies, and thus extracts the business cycle component from the extreme observations.

5. Stylized Facts

In this section we characterize the Swedish business cycle during the last 130 years by presenting some summary statistics for the nine time series in our data set. Following the tradition established by real-business-cycle analysts, we shall concentrate on the volatility of each series and its comovement with GDP.

Consider first the volatility of the series, as measured by their standard deviation. Table 1 displays the standard deviation of all our series, each expressed in percent of its own trend value. We present results both for the $\lambda$-series and for the $\Delta$-series and—for the sake of comparison—for the detrended series, as well as for the filtered series.

With regard to the relative volatility of the series, the results are robust across the four columns in the table. As expected the standard deviation of the filtered series on
average falls more relative to the detrended series for the \( \lambda \)-series. This is natural, since the Hodrick-Prescott filter shuts out less of the cyclical components corresponding to the lower frequencies than does the first-difference filter. For all series GDP and consumption are least volatile; investment, exports and imports are most volatile; and manufacturing production, hours, wages and productivity lie somewhere in-between. These stylized facts correspond fairly well to the available results for other countries and other time periods. See Backus and Kehoe (1989) for historical series of yearly data for several countries, Prescott (1986) for quarterly post-war data for the United States and Danthine and Girardin (1989) for quarterly post-war data for Switzerland, like Sweden a small open economy. All these studies eliminate the trend by the Henderson-Whitaker method, so their results are comparable to the left-most column in table 1. The following similarities and differences should be noted. First, investment is consistently in all studies found to be much more volatile than output and consumption. Second, the relative volatility varies across data sources. In post-war quarterly data consumption is less volatile than output. In historical yearly data the volatility is about the same also for other countries than Sweden. Third, employment, wages, and productivity appear somewhat less volatile than GDP in post-war quarterly data, while we find a standard deviation twice as high as that of GDP. Like in Switzerland, but unlike the U.S., productivity varies slightly more than employment. Fourth, we find investment to be equally volatile as exports and imports, whereas it is about twice as volatile in the post-war Swiss and U.S. data.

Consider next the comovement of the different variables, as measured by their correlation with GDP. Table 2a looks at the \( \lambda \)-series and displays the correlation coefficients between GDP and each of the other variables lagged one year, contemporaneous and leaded one year. As in Table 1 we show results both for the filtered and for the detrended series. Table 2b gives the same information for the \( \Delta \)-series.
Again the results are fairly robust across the four types of series. Most of the correlation coefficients are positive, indicating comovements between the variables. For most variables, the contemporaneous correlation coefficients are the highest. Of these, the correlation coefficients for private consumption are highest followed by those for manufacturing production, investment, and exports. The correlation coefficients for imports are lower, while they are close to 0 for wages and productivity (largely as a result of filtering). The latter two variables consistently seem to lead GDP, however. There is no particular sign of any variable lagging GDP. These results are generally similar to those for other countries and other time periods, possibly with the exception of the relatively marked lead in wages and productivity relative to GDP. Finally, we note that for some variables, the contemporaneous correlation coefficients are indeed higher for the filtered series than for the detrended series. Among the $\lambda$-series this is true for investment and hours, and among the $\Delta$-series it is true for investment, hours, exports, and imports. A possible interpretation is that the business cycle component is relatively more pronounced for these series.

6. Stability Over Time

The stylized facts in the previous section are statistics for the whole period 1861–1988. This period encompasses different stages in Sweden's development from a primitive agrarian economy to a modern industrialized economy. It is therefore legitimate to ask whether the stylized facts are stable across different subperiods.

Other authors have asked the closely related question of whether business cycles have been more volatile in the period after World War II than in earlier periods. The U.S. evidence is in dispute, largely due to the relatively poor quality of data for earlier periods. Romer (1989) and Balke and Gordon (1989) revised the pre-war data in various
ways. They looked at the ratio between the standard deviation of the deviations of GDP from trend pre-WWI and post-WWII. Romer found the ratio to be 1.3, while Balke and Gordon arrived at numbers around 1.7 employing different methods. Sheffrin (1988) investigated the same issue for five countries believed to have historical data of particularly high quality. For four of these (U.K., Norway, Italy and Denmark) the standard deviations of pre-WWI growth rates are only slightly higher than the corresponding standard deviation after WWII with ratios around 1.3. Only Sweden is an exception with a ratio of 2.5. For all countries the inter-war period stands out as more volatile than other periods. For Sweden Sheffrin relied on the work by Johansson (1967), which used the consumer price index from Myrdal (1933) to deflate GDP. Bergman and Jonung (1990) noted that data based on the improved deflators of Krantz and Nilson (1975) give rise to a much lower pre-war volatility bringing the same ratio down to around 1.5. They also investigated relative volatility for a number of other macroeconomic time series. Backus and Kehoe (1989) broadened the perspectives by looking at the major GDP components for a larger sample of 10 countries. They confirmed the picture of rather small decreases in GDP volatility between the pre- and post-war periods for most countries.

Let us now look at the development of our stylized business cycle facts over time. Rather than committing to comparison of specific subperiods, as other authors have done, we prefer to leave the partition of our data a bit more open, so we use a window of 41 years and compute moving statistics (standard deviations and correlations with GDP) over time. Figure 5 shows the results for the filtered \( \lambda \)-series (the results for the \( \Delta \)-series are qualitatively similar and not shown here.) When reading the figure, note that it is the center of the window that is displayed on the horizontal axis. The last observation, which is dated 1968, is thus the standard deviation for the subperiod 1948–1988.

What emerges from Figure 5 is a very clear hump-shaped pattern for all the
variables with the exception of investments and productivity. This pattern confirms that business cycles were distinctly less volatile in the pre-World War I period and in the post-World War II period than they were in the intermediate period including the wars and the depression. Most variables also exhibit more stability after WWII than before WWI. The difference is small for GDP but larger for consumption and even larger for investment, productivity, and employment.

In the middle of all this instability over time, there is nevertheless a striking symmetry. This is so particularly if one compares the inter-war period and the post-war period, periods which are comparable in terms of data quality but very different in terms of volatility. Look at the standard deviations for the 41 years centered on 1930 and 1968, respectively. The ratio between them is close to 2 for all of the nine variables in our data set (GDP: 1.89, manufacturing production: 2.14, private consumption 2.46, investments 2.16, exports: 1.81, imports: 2.84, hours: 2.13, wage: 2.10, and productivity: 2.55). This relative stability also holds for the Δ-series. Even though volatility has changed a great deal in absolute terms, it has hardly changed at all in relative terms.

We have also computed moving contemporaneous correlation coefficients between all variables and GDP for our filtered series. Figure 6 shows the results for the λ-series. (The results for the Δ-series again are similar.) Although there are some big changes over time—particularly for manufacturing production, productivity, imports and wages—many of the correlation coefficients are surprisingly stable over time. Most interesting is perhaps that the correlation coefficients do not seem to change systematically with the volatility of the series. Again, look at the 41 years centered on 1930 and 1968. Despite the difference in volatility during these two subperiods, there is a great deal of stability in the corresponding correlation coefficients. Manufacturing production remains most highly correlated with the coefficient decreasing slightly from .88 to .82. The only major change relates to wages where the correlation coefficient goes from .24 to -.46. For all the other variables the coefficients fluctuate
around .5 (private consumption goes from .65 to .45, investments from .58 to .56, exports from .54 to .64, imports from .34 to .54, hours from .43 to .50, and productivity from .54 to .50).

Taken together, we find the results in this section to be very interesting. On one hand, business cycles in Sweden since the 1860's have been quite discrete in the sense of different subperiods showing much variation in the joint volatility of all variables. On the other hand, business cycles have been quite similar in the sense of different subperiods showing little variation in the relative volatility of and comovements between different variables.

7. Conclusions

An important research program in macroeconomics aims at establishing stylized macroeconomic facts based on the properties of long time series. Most of the "facts" that researchers actually use, e.g. when calibrating and judging the performance of numerical equilibrium models of business cycles, are based on quarterly post-war data [Plosser (1989), Prescott (1986)]. This practice is somewhat doubtful for two reasons. First, these models are typically stochastic growth models, where the very long run properties are an important integral part of the performance of the model. Second, even disregarding the long-run dynamics it is of considerable interest to know whether the stylized facts are stable over time. Indeed, many of the models that are being calibrated abstract from economic policies and other institutional factors which have changed over time.

The issue of stability over long time periods is difficult to address for the U.S. economy due to the shortage of appropriate data. It is in this perspective we want to view our study of Swedish data based on a combination of labor market and national
accounts data for 128 years. We have chosen to filter our data in such a way as to concentrate on the intermediate frequencies typically associated with the term "business cycle." Our conclusions with regard to the stability of the business cycle facts are somewhat mixed. On one hand we reestablish the well known fact that the post-war period in general is much less volatile than the inter-war period and slightly less volatile than the pre-war period. On the other hand we show that there is a great deal of stability in relative variances of different variables and in correlations between different variables and GDP. We believe that these findings are very suggestive for subsequent theoretical and empirical modeling of business cycle fluctuations. They suggest that a natural candidate for a business cycle model that would fit the data well should have stable propagation mechanisms driven by a (set of) forcing variable(s) with heteroskedastic innovations.
References


Dahlgren, E. (1941), "PM med vissa beräkningar angående nationalinkomstens storlek" (Some Calculations of the National Income), in Statsverksprepositionen (the Government's Budget Proposal) 1941, Stockholm.


Appendix 1

Data Sources and Definitions

**GDP:**
GDP at fixed factor prices. For the period after 1950 GDP at fixed prices (millions of SEK) is constructed by dividing GDP at current prices by an implicit GDP deflator. The deflator is constructed by taking GDP at current market prices over GDP at fixed market prices.
1861–1949: Krantz and Nilsson (1975), Table 3.1.

**Manufacturing production (Q):**
Value added in manufacturing and mining at fixed producer prices.
1861–1949: Krantz and Nilsson (1975), Table 3.2.1, Column 2.

**Consumption: (C)**
Private consumption of goods and services at current prices deflated by the implicit GDP deflator.
1861–1949: Krantz and Nilsson (1975), Table 1:1.
Investments: (I)
Domestic investments in current prices divided by the implicit GDP deflator.
1861–1949: Krantz and Nilsson (1975), Table 1:1.

Exports: (X)
Exports of goods and services in current prices divided by the GDP deflator.

Imports: (M)
Imports of goods and services at fixed prices.
1861–1949: Johansson (1967), Table 52, Column 12.

Hours: (L)
Hours worked in manufacturing and mining.

**Wage:** (W)

Wage (in SEK/100 hours) per hour for workers in manufacturing and mining deflated by the implicit deflator for manufacturing production.

1861–1913: Bagge et al. (1935), Table 26, Column "Social Science Institute."
1914–1919: Bagge et al. (1935), Table 26, Column "Social Board."

**Productivity:** (Q/L)

Manufacturing production divided by hours.
Appendix 2

Description of the Filtering Procedure

We filter the detrended time series \( x(t) \) into the filtered series \( \bar{x}(t) \), \( t=1,\ldots,T \), in three steps.

First, we apply the Fourier transform

\[
z(\omega(j)) = \sum_{t=1}^{T} \exp(-i\omega(j)t) x(t); \quad \omega(j) = 2\pi j/T \pi; \quad j = -T/2, \ldots, T/2.
\]

A finite Fourier transform treats the data as being periodic with period \( T \), i.e. the data point before point 1 is identically equal with point \( T \). This can create problems at the endpoints of the time series, particularly if the observations are substantially different from zero. We tried to diminish these problems by "padding" each time series, where we added the same series both at the beginning and at the end of the series, before applying the Fourier transform.

Second, we choose a specific frequency band \([j, \tilde{j}]\) to define an indicator function

\[
I(j) = \begin{cases} 
1 & \text{if } j \in [\tilde{j}-1, \tilde{j}] \cup [j, \tilde{j}] \\
0 & \text{otherwise}
\end{cases}
\]

Third, we apply the inverse Fourier transform to that band,

\[
\bar{x}(t) = \frac{1}{2\pi} \sum_{j=-T/2}^{T/2} I(j) \exp(i\omega(j)t) z(\omega(j)); \quad t = 1,\ldots,T.
\]

The GAUSS programs that were used in the filtering procedure are available upon request from the authors.
Table 1
Standard deviations 1861 — 1988

<table>
<thead>
<tr>
<th></th>
<th>$\lambda$ — series</th>
<th>$\Delta$ — series</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Detrended Filtered</td>
<td>Detrended Filtered</td>
</tr>
<tr>
<td>GDP</td>
<td>3.55 1.84</td>
<td>3.00 2.22</td>
</tr>
<tr>
<td>Manufacturing production</td>
<td>8.30 3.83</td>
<td>7.00 4.35</td>
</tr>
<tr>
<td>Private consumption</td>
<td>3.86 2.14</td>
<td>3.39 2.57</td>
</tr>
<tr>
<td>Investment</td>
<td>12.84 7.56</td>
<td>13.33 9.19</td>
</tr>
<tr>
<td>Exports</td>
<td>15.68 6.93</td>
<td>13.58 9.21</td>
</tr>
<tr>
<td>Imports</td>
<td>16.87 10.61</td>
<td>17.53 14.06</td>
</tr>
<tr>
<td>Employment</td>
<td>6.07 3.45</td>
<td>5.49 3.93</td>
</tr>
<tr>
<td>Wages</td>
<td>8.59 3.23</td>
<td>6.34 3.75</td>
</tr>
<tr>
<td>Productivity</td>
<td>8.39 4.03</td>
<td>7.63 4.91</td>
</tr>
</tbody>
</table>
Table 2
Cross-correlations with GDP 1861 – 1988

a) $\lambda$ – series

<table>
<thead>
<tr>
<th></th>
<th>Detrended</th>
<th></th>
<th></th>
<th>Filtered</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-1</td>
<td>0</td>
<td>+1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Manufacturing production</td>
<td>0.625</td>
<td>0.761</td>
<td>0.575</td>
<td>0.358</td>
<td>0.571</td>
<td>0.136</td>
</tr>
<tr>
<td>Private consumption</td>
<td>0.634</td>
<td>0.791</td>
<td>0.468</td>
<td>0.230</td>
<td>0.683</td>
<td>0.174</td>
</tr>
<tr>
<td>Investment</td>
<td>0.330</td>
<td>0.558</td>
<td>0.400</td>
<td>0.237</td>
<td>0.614</td>
<td>0.163</td>
</tr>
<tr>
<td>Exports</td>
<td>0.431</td>
<td>0.630</td>
<td>0.461</td>
<td>0.179</td>
<td>0.573</td>
<td>-0.032</td>
</tr>
<tr>
<td>Imports</td>
<td>0.408</td>
<td>0.552</td>
<td>0.417</td>
<td>0.091</td>
<td>0.364</td>
<td>0.066</td>
</tr>
<tr>
<td>Employment</td>
<td>0.077</td>
<td>0.330</td>
<td>0.325</td>
<td>0.083</td>
<td>0.421</td>
<td>0.080</td>
</tr>
<tr>
<td>Wages</td>
<td>0.562</td>
<td>0.395</td>
<td>0.176</td>
<td>0.341</td>
<td>0.069</td>
<td>-0.047</td>
</tr>
<tr>
<td>Productivity</td>
<td>0.538</td>
<td>0.499</td>
<td>0.332</td>
<td>0.234</td>
<td>0.224</td>
<td>0.131</td>
</tr>
</tbody>
</table>

b) $\Delta$ – series

<table>
<thead>
<tr>
<th></th>
<th>Detrended</th>
<th></th>
<th></th>
<th>Filtered</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-1</td>
<td>0</td>
<td>+1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Manufacturing production</td>
<td>0.265</td>
<td>0.511</td>
<td>0.167</td>
<td>0.275</td>
<td>0.491</td>
<td>0.020</td>
</tr>
<tr>
<td>Private consumption</td>
<td>0.113</td>
<td>0.709</td>
<td>0.055</td>
<td>0.025</td>
<td>0.679</td>
<td>0.035</td>
</tr>
<tr>
<td>Investment</td>
<td>0.064</td>
<td>0.481</td>
<td>0.105</td>
<td>0.022</td>
<td>0.578</td>
<td>0.063</td>
</tr>
<tr>
<td>Exports</td>
<td>0.170</td>
<td>0.538</td>
<td>0.072</td>
<td>0.096</td>
<td>0.640</td>
<td>-0.147</td>
</tr>
<tr>
<td>Imports</td>
<td>0.151</td>
<td>0.355</td>
<td>0.108</td>
<td>0.001</td>
<td>0.363</td>
<td>-0.001</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.029</td>
<td>0.349</td>
<td>0.146</td>
<td>-0.090</td>
<td>0.518</td>
<td>0.065</td>
</tr>
<tr>
<td>Wages</td>
<td>0.376</td>
<td>0.150</td>
<td>-0.014</td>
<td>0.365</td>
<td>-0.113</td>
<td>-0.147</td>
</tr>
<tr>
<td>Productivity</td>
<td>0.254</td>
<td>0.222</td>
<td>0.064</td>
<td>0.280</td>
<td>0.053</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Notes to the Figures

Figure 1 shows the natural logarithm of the series described in Appendix 1.

Figure 2a and 3a show the natural logarithm of the spectra for the $\lambda$–series and the $\Delta$–series, respectively, plotted against frequency, defined as cycles per whole period of 128 years (127 for the $\Delta$–series). The spectra are not normalized, that is, the area under the spectra does not equal unity.

Figure 2b and 3b show the coherence between GDP and each of the other variables, for the $\lambda$–series and $\Delta$–series, plotted against frequency.

Figure 4 shows the natural logarithm of a few of the detrended and the filtered series. Four paddings are used (see Appendix 2).

Figure 5 shows moving standard deviations of the natural logarithm of the series, with a moving window of 41 years.

Figure 6 shows moving correlations of the natural logarithm of the series, with a moving window of 41 years.
Figure 2b. Coherence with GDP, $\lambda$ series
Figure 3a. Spectrum, Δ-series
Figure 3b. Coherence with GDP, Δ-series
Figure 5. Moving standard deviations
Figure 6. Moving correlations with GDP