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Stock Markets and Business Cycle Comovement in Germany before World War I: Evidence from Spectral Analysis

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Stock Markets and Business Cycle Comovement in Germany before World War I: Evidence from Spectral Analysis [1]

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Abstract

This paper examines the comovement of the stock market and of real activity in Germany before World War I under the efficient market hypothesis. We employ multivariate spectral analysis to compare rivaling national product estimates to stock market behavior in the frequency domain. Close comovement of one series with the stock market enables us to decide between various rivaling business cycle chronologies. We find that business cycle dates obtained from deflated national product series are severely distorted by interference with the implicit price deflator. Among the nominal series, the income estimate of Hoffmann (1965) correlates best with the stock market, while the tax based estimate of Hoffmann and Müller (1959) is too smooth especially before 1890. We find impressive comovement between the stock market and nominal wages, a sub-series of Hoffmann's income estimate. We can show that a substantial part of this nominal wage series is driven by data on real investment activity. Our findings confirm the traditional business cycle chronology for Germany of Burns and Mitchell (1946) and Spiethoff (1955), and lead us to discard later, rivaling business cycle chronologies.

Keywords: Business Cycle Chronology; Imperial Germany; Spectral Analysis; Efficient Market Hypothesis

JEL codes: E32, E44, N13

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1 Introduction

Among the industrialized countries, Germany compares relatively favorably as regards our knowledge about national income and output in the 19th century. For Germany, four different estimates exist that go back to the early 1850s. However, there are major differences between these series regarding both trends and business cycle characteristics.

All available estimates rest on the seminal work of Hoffmann (1965) and earlier work of Hoffmann and Müller (1959). Hoffmann and his collaborators collected and aggregated a vast amount of data to produce independent estimates of output, expenditure, factor income-cum-employment, and the income tax base. The inevitable inconsistencies and deviations have generated a literature that called for improvements and corrections of the most obvious problems (Fremdling 1988, Fremdling 1995, Holtfrerich 1980).

Recent work by Burhop and Wolff (forthcoming) is a systematic attempt to apply these corrections and obtain revisions of all four data series for the pre-1913 period. They also present a compromise estimate, which is an unweighted average of the existing data. Their ambitious contribution is intended to put an end to the debate about the main trends of German economic growth in the 19th century and the implied business cycle chronology.

The work by Burhop and Wolff (forthcoming) is an important improvement to the various series. However, even these improved series exhibit business cycle chronologies that are inconsistent with each other, and that contradict the business cycle dating of an older literature employing disaggregate evidence, most prominently Burns and Mitchell (1946) and Spiethoff (1955).

The present paper sets out to shed further light on the issue by introducing additional information. We refrain from refining one or the other of Hoffmann's series, which given the improvements made by Burhop and Wolff (forthcoming) would be subject to decreasing returns. Instead, our approach is to exploit the information content in a completely different set of data that has been neglected in the debate so far, namely financial data. After 1870, when the stock market law in Germany was deregulated massively, a public offering boom set in. It resulted in a ratio of market capitalization to GDP of over 40 percent, a level that was only reached again in the 1990s (Rajan and Zingales 2003). Thus, stock prices reflected information on a substantial portion of the German economy.

According to established asset pricing models, stock prices should be procyclical and lead the business cycle (Campbell, Lo, and MacKinlay 1997, Cochrane 2001). There is also a connection between asset prices and real investment: neoclassical theory predicts that if adjustment of capital stock is resource or time intensive,

asset prices should be a predictor for real investment (Hayashi 1982, Kydland and Prescott 1982). Our idea is to exploit this link between asset prices and real business activity to help determine the business cycle chronology in Germany before World War I. To this end, we explore the frequency domain characteristics of the various national income estimates, and apply a bivariate coherency measure to assess which of the series are best explained by the stock market.

Research over the recent years has brought substantial advances in the construction of representative stock market indices for Germany prior to World War I, with new indices constructed by Eube (1998) and Ronge (2002). As each index has its own comparative advantage, we employ them alongside each other.

Ideally, one would want to study the bivariate coherence between each of these stock market indices and real national product and income. However, upon examining the univariate spectra of the various different candidate estimates of national product and their coherence with the stock market index, we find the cyclical characteristics of most series to be obfuscated by deflating: application of a deflator to a nominal estimate seriously affects its cyclical characteristics. For this reason, we focus much of our attention on nominal series, both for national product and stock market prices. Hoffmann's (1965) income/employment series turns out to be closest to the stock market, whereas Hoffmann and Müller's (1959) income tax series, despite its plausible information on levels, is too smooth before 1890. Nominal wages as a subseries of Hoffmann's (1965) income/employment series trail the stock market by one to two years, and both series show an impressive comovement across all cycles between 1870 and 1914. In that period the German economy experienced six cycles with an average length of 7.5-8 years. These results square well with the findings of Metz (2002) for 20th century Germany, while A'Hearn and Woitek (2001) find a slightly longer cycle in German pre-WW I industrial production data.

Our results are also supported by disaggregate indicators on real activity. We can show that nominal stock prices and nominal wages do not only represent price movements, but comove with real business cycle indicators such as railway transport, and iron, coal and steel production. The results are pretty much in line with Burns and Mitchell's (1946) reference turning points, also Spiethoff's (1955) *Wechsellagen* are mainly confirmed. At the same time, Burhop and Wolff's (forthcoming) compromise estimate performs very poorly.

We present our findings in the following order: The next section includes a more detailed discussion of the relevant research. In Section 3, a brief presentation of the stock market data follows. Section 4 provides some intuition for our application of spectral analysis. Results are presented and discussed in Section 5. Section 6 concludes and explores avenues for further research.

2 Conceptual Issues

Two different strands of literature have to be merged for our project. One is the German historical national accounting literature, starting with Hoffmann and Müller's (1959) approach to estimate the net national product (NNP) from (mainly) Prussian income tax data.[2] The other strand of literature is about the connections between asset prices and output. Consumption-based asset pricing models justify theoretically why stock prices can be used as a leading indicator of output. Capital-based asset pricing models argue that the stock market predicts future real investment and hence output.

All work on German aggregate data in the 19th century is based on the work of (Hoffmann 1965). His estimates of national product and income have experienced a long history of criticism, and today are regarded as highly problematic (Burhop and Wolff forthcoming, Ritschl 2004, Ritschl and Spoerer 1997, Fremdling 1988, Schremmer 1987, Holtfrerich 1983). Nevertheless, they are still widely used, especially in international data sets (Craig and Fisher 2000, Maddison 1995). Burhop and Wolff (forthcoming) present a comprehensive overview of the improvements on Hoffmann's (1965) and Hoffmann and Müller's (1959) series, in addition to their own substantial efforts in this regard. The starting point of their work is an upward revision of the capital stock and investment series, along with a new series of returns on capital. As pointed out by Schremmer (1987), Hoffmann's own estimate of capital had a systematic downward bias, while his series of returns on capital was a simple static estimate of 6.68 percent. Correcting for this bias affects three of the four series of Hoffmann (1965). The income tax estimate of national income remains unaffected. Here the revision by Burhop and Wolff (forthcoming) is limited to accounting for indirect taxes and depreciation, extending a revision made by Ritschl and Spoerer (1997).

Unsurprisingly, the four series of Hoffmann (1965), even accounting for all later corrections, are mutually inconsistent with regard to both levels and cyclical fluctuations. We aim to decide between these rivaling series based on the cyclical behavior of asset prices, measured by the stock market. The consumption-based asset pricing model links aggregate consumption to asset returns. Under suitable assumptions about the representative agent's utility function it predicts that the price of an asset is positively correlated with the expected future payoff from the asset, valued by the stochastic discount factor that depends on utility of the representative agent. (Campbell, Lo, and MacKinlay 1997, Cochrane 2001). Note also that stock price indices are utilized in business cycle forecasting as leading indicators (U.S. Bureau

[2]Hoffmann and Müller's work was essentially the backward extension of a series by Germany's Statistical Office (Statistisches Reichsamt 1932) that went back to 1890.

of Economic Analysis 1984).

Another way to think about the link between stock prices and real activity is Tobin's Q (Tobin 1969). It is a measure of the marginal revenue from investing in a firm or not. This depends on the ratio of the market value of the firm's assets to their replacement cost, called Q. If the adjustment of a firm's capital to its optimal value is either costly (Hayashi 1982) or time-consuming (Kydland and Prescott 1982), this ratio may diverge from one. Whenever it is greater than one, more will be invested. But as returns to capital are diminishing, the ratio will always converge back to unity, where an additional unit of capital equals its replacement cost. Theoretically this model is very appealing, but empirical applications have led to low regression coefficients between investment and Q, albeit significant ones. (Hayashi (1982) estimates 0.04 for US-data.)

For our purpose, however, it is sufficient to examine the predictive properties of asset prices for the business cycle. As we are working in the frequency domain, the amplitude of any comovement, related to the regression coefficient, is immaterial. The information we intend to exploit comes solely from frequency.

3 Data

We employ two sets of data: the first consists in four estimates of net national product (NNP), taken from Hoffmann (1965) and Hoffmann and Müller (1959). The second set of data includes two stock price indices, which we introduce to gain additional information on the cyclical behavior of the German economy. Further below, this second set of data will be widened to include sectoral evidence on real investment activity.

The NNP series start in the early 1850s, but the stock price indices are only available beginning in 1870 (Ronge 2002) or 1876 (Eube 1998), following legislation in 1870 that lifted a de facto ban on joint stock companies in most parts of Germany. Thus for the quantitative analysis, only 44 data points can be used if Ronge's index is employed, and only 38 in the case of Eube's index. This data restriction has important methodological implications, as will be explained later.

3.1 The NNP Series

Net national income and output is estimated by Hoffmann (1965) in three different ways, approaching NNP from output, expenditure and income (which is how the series will be named hereafter.) The fourth series in Hoffmann & Müller (1959) estimates the NNP from the income side as well, but uses income tax data to do so. Therefore we call it Taxes.

Hoffmann's (1965) "Income" series is estimated as the sum of average annual wages and profits, weighed by estimated labor and capital inputs. The wage series is mainly calculated from social security statistics, enriched with daily wage data from the duchy of Baden in south-west Germany, whereas capital income is the capital stock times return on capital. Hoffmann (1965) originally assumed the return on capital to be constant at 6.68% for the whole period of 1850-1913. For our purpose, we employ an improved profit estimate by Burhop and Wolff (forthcoming), who calculated a new return series from the dividend yields of joint stock companies. The resulting series yields national income at nominal factor cost. It is commonly deflated by Hoffmann's (1965) implicit NNP deflator.

"Expenditure" is the sum of private and public consumption, investment and exports minus imports. These series are calculated from various sources, where some are originally in current prices and deflated, and others in volumes and connected to a prices series afterwards. Because of this it is not possible to entirely filter out the possible bias from deflating on this series.

Hoffmann's investment series is just the annual net change of the capital stock. It is an extrapolation of the capital stock of the grand duchy of Baden, derived from capital tax data. A first revision of this series was presented by Schremmer (1987). Burhop and Wolff (forthcoming) applied further revisions, which we adopt here as well.

"Output" is constructed as a volume index of physical production, spliced to an estimate of value added in 1913. The twelve series are weighted by the number of workers in each sector and of census data on the value added per capita in 1936. (Burhop and Wolff forthcoming) use additional employment data and use the new capital stock value for 1913 for their improved version of the "Output" estimate. Since this series was originally constructed from volume indices, it has to be inflated to analyze it in current prices.

One entry of the aggregate output series that has received major attention is industrial Production (IP). The IP index has recently been subject to major revisions. Ritschl (2004) revises the income-based metal making and processing series with output data and obtains very different results for post-1913. Burhop (2005) presents a revised IP series up to 1913 that includes additional data and corrections for a number of flaws in Hoffmann's (1965) calculation. Fremdling (2005) has recently revised the industry census data for 1936. However, these revisions affect mostly the level of output, less so its cyclical behavior, which is of interest here. Metal making and processing, which are closely related to fixed investment, may be an exception. This is one reason why further below, we will look at alternative series capturing activity in that sector.

Finally, "Taxes", the series by Hoffmann and Müller (1959), is based on income

tax data for all of Germany from 1891 on. For earlier years, data from Prussia and some other states is used. The overall quality of this series is generally considered to be good beginning in the 1890s. Ritschl and Spoerer (1997) rely heavily on this series in their construction of a long term index of German GNP for the 20th century. Burhop and Wolff (forthcoming) see this series as the most reliable source of information on GNP levels between 1850 and 1913. Still, prior to 1890 the cyclical information in the "Taxes" estimate of national income seems poor. Following Jeck (1970), we suspect this is due to the tax code prevailing to 1890. Up until that year, income taxes in Prussia as well as most other German states were mostly levied as a three-year moving average of past incomes. As a consequence, the Taxes series is itself largely a moving average of national income prior to 1890. Unsurprisingly, applying the price deflator to this artificially smooth estimate of national income leads to an estimate of real income that is the most volatile of all. This is similar to the spurious volatility phenomenon observed by Romer (1986, 1989) for U.S. historical data.

3.2 The Stock Market Indices

Each of the two stock market series employed here was constructed for its own particular purpose (Graph 1). Ronge's (2002) series is a backward extrapolation of the German DAX index, which includes the 30 most important stocks, annually chosen by their market capitalization. In contrast, the index by Eube (1998) aims to cover as many firms as possible, and thus his index consists of 415 companies in 55 sectors. Thus, while the Ronge index is a typical blue chip index akin to the Dow Jones, the Eube index could roughly be compared to the much broader Standard & Poors 500.

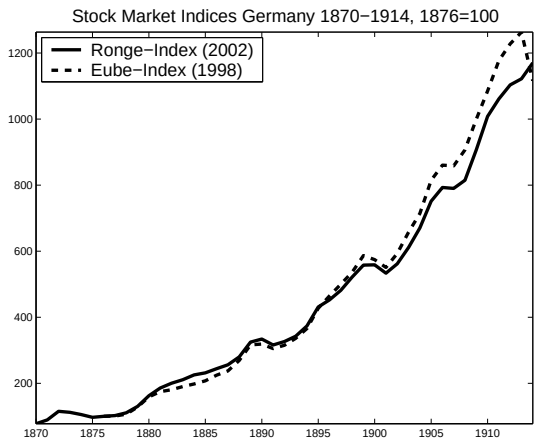

Figure 1: Stock market indices by Ronge (2002) and Eube (1988).

Unfortunately, Eube's (1998) index has three drawbacks. First, it starts only in 1876, which swallows more than ten percent of the data points. Second, Eube (1998) does not consider ten of the biggest railroad companies that were included in Ronge's (2002) index, without justifying this decision. Ronge (2002, p. 167) argues that this might be the reason for the relatively bad performance of Eube's index in the 1880s. Railway stocks did relatively well during that period, because of the huge compensations paid to the owners after the nationalizations of the 1870s/80s.

Eube (1998) neither accounts for a component of the yield, the so-called *Stückzins-Usancen*, a fixed interest paid on a stock in addition to dividends. This omission is likely to affect only the intra-year movement of a stock, but we cannot exclude the possibility of bias also at an annual frequency. We will mostly work with Ronge's (2002) index, and use Eube's index only to check for robustness.

4 The Tool: Spectral Analysis

A simple correlation coefficient could measure which of the various NNP estimates is closest to the stock market. However, this approach would have a serious drawback: the series might be forward or backward shifted in time, but still represent the same business cycle. Spectral analysis, however, abstracts from calendar time and represents a series by its frequency. To do this, a transformation of the series from the time domain to the frequency domain is required. In addition, multivariate applications are needed that provide analogs to regression coefficients and statistics.

4.1 Basics and Application

According to *Fourier's* theorem, any periodic function can be represented as a (possibly infinite) sum of weighted sine and cosine waves (Priestley 1981). One way to express the frequency content of a stochastic discrete time series x_t is to transfer its autocovariance sequence to the frequency domain by multiplying it at every lag k by a complex-valued factor $e^{-ik\omega}$. [3]

$$S_{xx}(\omega) = \sum_{k=-\infty}^{\infty} \gamma(k)\, e^{-ik\omega}, \tag{1}$$

where $\gamma(k)$ is the autocovariance sequence of x_t, and i is the imaginary number $\sqrt{-1}$. The result is called *power spectral density* (*PSD*) and is a summary of the frequency content of a time series. It is represented as a graph that peaks at the frequency ω which dominates the series. In Figure 2 we used a moving-average filter

[3] According to DeMoivre's theorem, $e^{-ik\omega}$ is just another way of writing the sum of sine and cosine waves: $e^{-ik\omega} = cos(k\omega) - i \cdot sin(k\omega)$.

to extract shares of the variance of a monthly time series differing by frequency. The upper left graph contains only variance due to a cycle length between three and twelve years, i.e. after filtering out variance with higher or lower frequency.[4] The lower left graph contains variance due to a cycle length between two and 24 months. Their respective power spectra[5] are plotted in the right column. The upper time series is moving slowly through time, i.e. it is dominated by low frequencies. That corresponds to a peak close to the origin. Here we find it at ca. 0.1 radians, which represents a cycle of $2\pi/0.1 \approx 63$ months or 5 1/4 years.

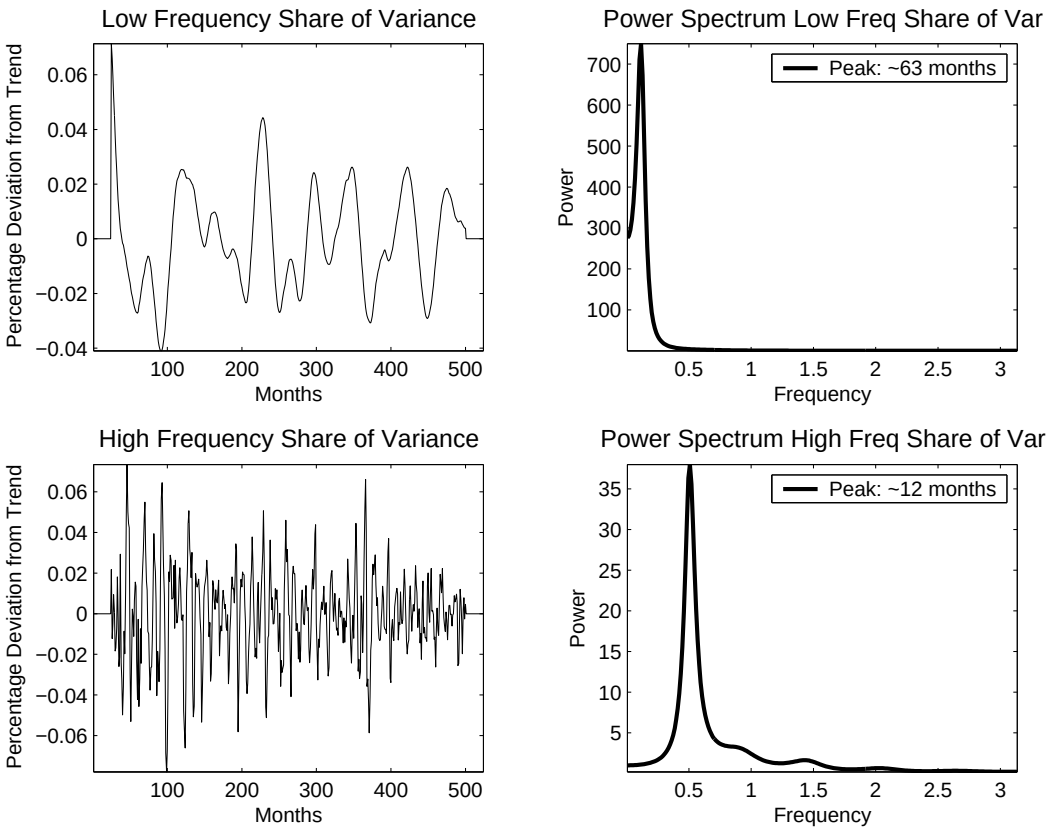

Figure 2: High- and low-frequency share of the variance of a monthly time series and their respective power spectra.

The lower series has more cycles per unit of time, and thus is dominated by higher frequencies. The peak shifts to the right, and with $\omega = 0.5$ the cycle takes $2\pi/0.5 \approx 12 - 13$ months.

The frequency content of a time series can also be described as the variance of a time series ordered by frequency. Accordingly, the area under the spectrum is the

[4]Recall that high frequency corresponds to short cycles and low frequency to long cycles.

[5]The difference between a *power spectrum* and a *power spectral density* is that the area under the *power spectral density* is normalized to one, while the area under the *power spectrum* varies.

total variance of the series. The area between two specified values of ω then is the share of variance corresponding to a certain range of frequencies, e.g. business cycles of a length between 7 and 10 years.

For our application we need to look at two time series and their *cross spectral density*. This can be represented as the *Fourier*-transform of the covariance sequence $\rho(k)$ of the time series x_t and y_t

$$S_{xy}(\omega) = \sum_{k=-\infty}^{\infty} \rho(k) e^{-ik\omega}. \tag{2}$$

The *cross spectral density* is used to obtain the *squared coherency* measure, which is defined similarly to a correlation coefficient as

$$C_{xy}(\omega) = \frac{|S_{xy}(\omega)|^2}{S_{xx}(\omega) S_{yy}(\omega)}. \tag{3}$$

Squared coherency shows to which extent x_t and y_t are linearly related to one another, so for every ω it yields a number $0 \leq C_{xy} \leq 1$.

Squared coherency is used to calculate the frequency domain counterpart to R^2 (the coefficient of determination) that tells us the share of x_t's variance explained by y_t with respect to ω. The total variance of series x, $Var(x_t) = \int_{-\pi}^{\pi} S_{xx}(\omega) d\omega$, can be decomposed into an explained and an unexplained component such that:

$$\int_{-\pi}^{\pi} S_{xx}(\omega) d\omega = \int_{-\pi}^{\pi} C_{yx}(\omega)\, S_{xx}(\omega) d\omega \; + \; \int_{-\pi}^{\pi} S_e(\omega) d\omega, \tag{4}$$

where the left hand side is $Var(x_t)$, the first term of the right hand side is the variance explained by y_t and the second term is unexplained variance. In the results section we will use the ratio of explained variance to total variance to get the

$$\text{share of explained variance} = \frac{\int_{-\pi}^{\pi} \mathrm{C_{yx}}(\omega)\, \mathrm{S_{xx}}(\omega) \mathrm{d}\omega}{\int_{-\pi}^{\pi} \mathrm{S_{xx}}(\omega) \mathrm{d}\omega} \tag{5}$$

expressed as a percentage number. Sometimes it can be of interest how much of the shared variance at certain frequencies is shifted in time relative to the variation of the explaining series. This measure can be obtained by recalling that *cross spectral density* is a complex number consisting of a real and an imaginary part $r_{xy}(\omega)$, and $q_{xy}(\omega)$

$$S_{xy}(\omega) = r_{xy}(\omega) - i q_{xy}(\omega), \tag{6}$$

where r_{xy} is the *co-spectrum*, i.e. the *in-phase* share of variation and q_{xy} the *quadrature spectrum*, the *out-of-phase* share of variation.

Using that definition *squared coherency* can be split up into

$$C_{xy}(\omega) = \frac{|(S_{xy}(\omega)|^2}{S_{xx}(\omega)S_{yy}(\omega)} = \frac{r_{xy}^2(\omega) + q_{xy}^2(\omega)}{S_{xx}(\omega)S_{yy}(\omega)}. \tag{7}$$

Then the explained variance measure (4) can be further decomposed into

$$\int_{-\pi}^{\pi} S_{xx}(\omega)d\omega = \int_{-\pi}^{\pi} C_{yx}(\omega)\, S_{xx}(\omega)d\omega \; + \; \int_{-\pi}^{\pi} S_e(\omega)d\omega$$

$$= \int_{-\pi}^{\pi} \frac{r_{xy}^2(\omega) + q_{xy}^2(\omega)}{S_{xx}(\omega)S_{yy}(\omega)}\, S_{xx}(\omega)d\omega \; + \; \int_{-\pi}^{\pi} S_e(\omega)d\omega$$

$$= \int_{-\pi}^{\pi} \frac{r_{xy}^2(\omega)}{S_{xx}(\omega)S_{yy}(\omega)}\, S_{xx}(\omega)d\omega \; + \; \int_{-\pi}^{\pi} \frac{q_{xy}^2(\omega)}{S_{xx}(\omega)S_{yy}(\omega)}\, S_{xx}(\omega)d\omega \; + \int_{-\pi}^{\pi} S_e(\omega)d\omega, \tag{8}$$

producing the explained variance of one series *in-phase* and *out-of-phase* of another series.

4.2 Filtering

Typically, national product series contain a time trend and/or a unit root (Granger 1969). Trends or unit roots are, when seen from the frequency domain, variations with a very low frequency. Series exhibiting these characteristics deviate from the mean more strongly than their high frequency counterparts and thus request a higher share of the series' total variance. Thus the spectrum of a trended series would always peak at very low frequencies, irrespective of any cyclical behavior. For that reason, most economic time series need to be detrended in order to make peaks at business cycle frequencies visible in the power spectrum in normalized fashion in the *power spectral density (PSD)*.

Filtering, or rendering a time series stationary, however, is a difficult task, since it might distort the frequency content of the remaining cyclical part. Simple first-differencing or taking growth rates has proven to severely bias a series towards higher frequencies. Under first-differencing, the peak in Figure 2 would artificially be shifted to the right (Hamilton 1994, p. 177).

For this reason, we will use the popular Hodrick-Prescott filter[6]. Canova (1998) and Cogley and Nason (1995) have argued that the HP filter also distorts the frequency content of a non-stationary time series if the series contains a unit root. For this reason, we have also repeated our exercises with a modified version of the Baxter-King filter, which has good properties both in the case of stationarity or

[6]We employ a λ value of 6.25, as recommended by Ravn and Uhlig (forthcoming) for annual data.

non-stationarity (Baxter and King 1999). The modification we employ relative to Baxter and King's (1999) filter consists of applying Lanczos' *σ-factors* that solve the problem of spurious side-lobes (Woitek 1998, Woitek 2001). However, this has the disadvantage of taking away k data points according to the length of the moving-average window. Thus we employ the Baxter-King-filtered series only for robustness checks. Generally we find that Baxter-King filtered series have cycles that are about six months longer than Hodrick-Prescott-filtered ones.

4.3 Spectral Estimation

The definition of *power spectral density* given in equation (1) requests unlimited data, namely the autocorrelation sequence $\gamma(k)$ for $-\infty \leq k \leq \infty$. In reality we need to approximate this measure by a finite-dimensional estimation.

Non-parametric estimators elegantly calculate the *PSD* directly from the data. Unfortunately, they are inconsistent, but the estimator's variance can be reduced by averaging over segments of the data. This increases the amount of data needed, which makes them ill suited for our purpose.

Parametric estimators specify a time series model for the given process, the parameters of which are estimated from the data in the time domain. Then the parameters are transformed to the frequency domain. This second method is less data demanding, but depends on the right time series model.

Given that our national product and income series are available only at an annual frequency, we face a small sample and thus rely on parametric estimation. Broersen (2000) shows that for small samples, parametric estimators yield better spectral estimates than non-parametric estimators. We will estimate a bivariate vector autoregression (VAR) model, which is the most common approach in the literature. A'Hearn and Woitek (2001) use a VAR(5) to estimate explained variance between IP-series from various countries in the late 19th century. To ensure comparability across our estimates, we employ a lag length of $p = 3$ for all VAR models.[7]

In principle, the VAR-parameters could be obtained by OLS, but we prefer a multivariate version of the Burg method, which yields better estimates than OLS (Trindade 2000). It minimizes the mean of the forward- and the backward prediction error. The multivariate version was developed by Strand (1977) and Morf and A. Vieira (1978).[8]

[7]We experimented with higher order VARs, however with little effect on the frequency-domain results. There are fundamental reasons why this is so, see Priestley (1981).

[8]For a discussion of the Nuttall-Strand method, refer to Marple (1987).

5 Results

5.1 Real vs Nominal Variables

In this section we first show that the deflated NNP series, although employed intensively in the literature so far, can be bad indicators for the business cycle. Instead we propose to examine nominal variables. In a second step, we validate our results by looking at sectoral indicators of physical production such as iron and steel production, which corroborate our findings.

Next, note that we can only compare three series in current prices with each other, because Output was partly constructed in volumes, not in values, and thus is originally a convolution of real and deflated nominal data. To transform Output into a fully nominal series, we would have to introduce prices by force, thus creating the bias we want to avoid here. However, for completeness we will compare Output to our small set of disaggregate real indicators and show that it is far from performing well.

Comparing the other NNPs in current prices to the deflated NNPs (Figure 3) leads to at least three observations: First, nominal Expenditure and nominal Income differ in levels but exhibit similar movements. The reason for the level difference is that Expenditure is measured at market prices while Income (as well as Taxes) is measured at factor cost. Second, Taxes is smoother than the other two series, and starts at a markedly higher level. Third, the cyclical properties of all three series change severely after deflating. This is especially true for Taxes.

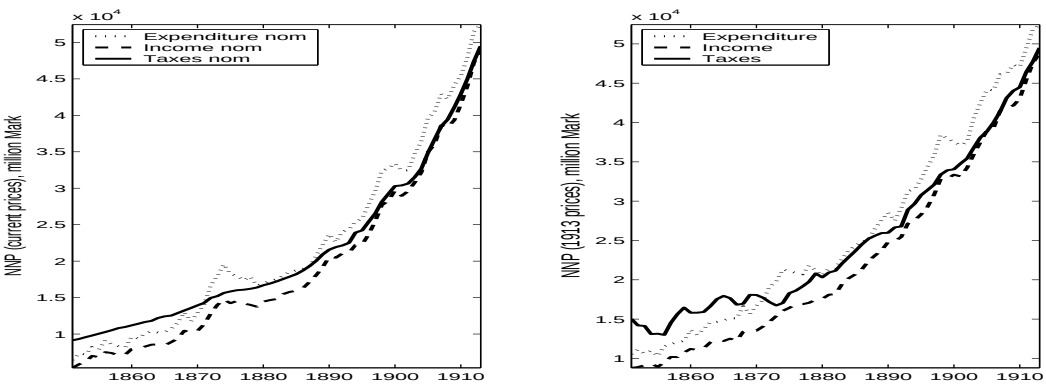

Figure 3: NNP (current prices) Germany 1851-1913.

It is very smooth in current prices, but extremely variable after deflating. This is a German version of the spurious volatility problem in historical time series described by Romer (1986, 1989) for U.S. data. In contrast, deflating the Income series appears to reduce its volatility, especially before 1890. In particular, the hump exhibited by

the original (nominal) Income series in the 1870s almost disappears. Expenditure seems to increase in volatility through deflation after 1890, and a marked kink is introduced into the time series just prior to 1900.[9]

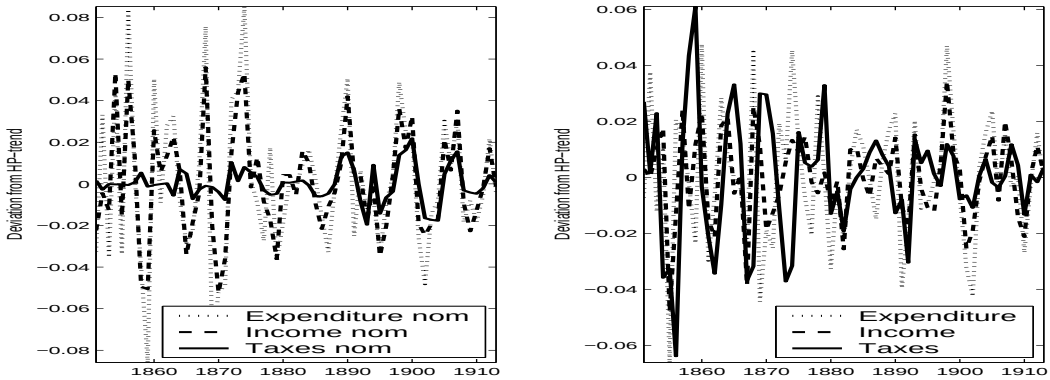

Figure 4: NNP (current prices), deviation from trend, Germany 1851-1913.

Turning to the cycles around the HP(6.25)-trend (Figure 4) it becomes clear that the nominal series exhibit a much clearer picture than the deflated series. This is surprising, as one should expect the correlation between the different series to increase when multiplying them with the same price index. The explanation is twofold: First, Taxes' is up to 60 percent higher in levels than the other series. Thus, multiplying it with the deflator, which can be as big as 1.74, results in much bigger changes. Second, the deflator and Income and Expenditure partly cancel each other out, so that variation decreases.

Burhop and Wolff (forthcoming) focused exclusively on the deflated series, and argued that there may have been a downturn in the early 1870s. Indeed, the deflated Taxes series exhibits a downturn around various trend measures (pp 8ff). They also notice that Taxes exhibits a larger variance than Income and Expenditure (pp 13f). However, those observations are caused by deflating the nominal series with Hoffmann's (1965) price index that went up in the early 1870s, and is very volatile before 1880 (Figure 10).

The descriptive evidence examined in this section suggests that the cycles in the real series are anything but clear, and that any conclusions about the nature of the German business cycle based on these series alone run the risk of being a figment of the deflation procedure. For this reason, we choose a different approach and look at the original, nominal series first. In a second step, we will evaluate the extent to which fluctuations in the nominal series may have been caused by price movements.

[9]Note that we refer to Hoffmann's (1965) series and not to Burhop and Wolff's (forthcoming) revised series to make sure the change is due to deflating alone.

5.2 Comovement of Nominal Variables with the Stock Market

The evidence gathered in the previous section can be supplemented by looking at the cyclical behavior in a more methodological way. Figure 5 shows the explained variance of Expenditure and in terms of Ronge's (2002) stock market index (hereafter "Ronge"). Explained variance is the ratio of the heavy grey area relative to the sum of the light and the heavy grey area.[10] Since explained variance is not symmetric (i.e. the variance of x_t explained by y_t is not the same as the variance of y_t explained by x_t, similar to R^2), we present an arithmetic average of the two values at hand.

Baxter-King-filtered data are presented where necessary as well as variance explained by Eube's (1998) index. Here we find that 58 percent of the variance in Expenditure is explained by Ronge's stock market index (see Table 1). Together, the two series follow a common cycle of 7 years and 2 months.

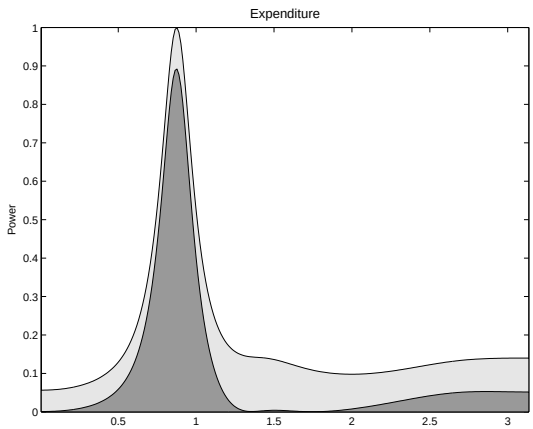

Figure 5: Explained variance of Expenditure in terms of Ronge's stock market index.

Results for Income are provided in the left panel of Figure 6. Ronge's stock market index explains 61 percent of the variance in Income, with the same cycle length as in Expenditure.

The right panel of Figure 6 shows the variance in Taxes explained by the Ronge index. The area under the dotted line covers only 46 percent of the total area that represents total variance. The cross spectrum peaks at 6 years and 10 months.

Table 1 provides an overview of the analyzed series. It provides full coverage of the original series of Hoffmann (1965) and Hoffmann and Müller's (1959), along with the revisions of these series by Burhop and Wolff (forthcoming). We present results for HP-filtered as well as Baxter-King filtered series. Additionally, results

[10] We cover the frequency range of 3-10 years, i.e. common cycles of longer or shorter duration do not contribute to explained variance.

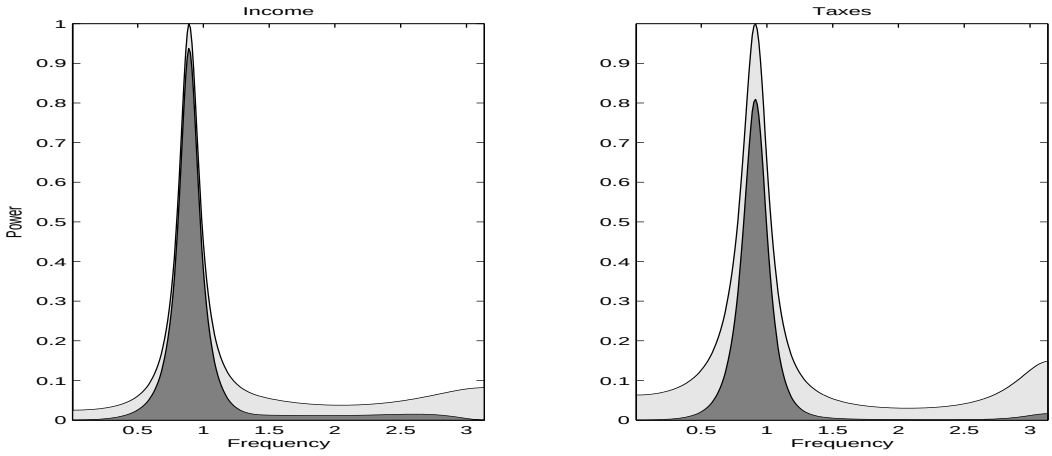

Figure 6: Share of variance in Income and Taxes explained by Ronge's stock market index.

	Burhop and Wolff (forthcoming)				Hoffm. (1965), H./M. (1959)			
	Output*	Exp.	Income	Taxes	Output*	Exp.	Income	Taxes
HP, 3-10 y.	25%	46%	61%	46%	43%	58%	62%	44%
HP, 7-10 y.	8%	24%	27%	17%	15%	31%	31%	11%
BK, 3-10 y.	31%	30%	55%	46%	32%	47%	52%	44%
BK, 7-10 y.	7%	22%	32%	21%	16%	26%	31%	21%

HP: Hodrick-Prescott (6.25), BK: modified Baxter-King (K=3, 2-15 years band), VAR(3)

*Output in real terms

Table 1: Shares in variances of nominal NNP-series (plus Output) explained by Ronge's (2002) stock price index.

for the explained variance are provided for two different frequency bands: the first corresponds to 3-10 years, which covers Kitchin and Juglar cycles, and the second the narrower band of 7-10 years, which corresponds only to Juglars.

The table shows that Income is explained better by Ronge's stock market index than are Expenditure and Taxes.[11] The bad performance of Taxes confirms a suspicion by Jeck (1970) and Burhop and Wolff (forthcoming): Before 1890, the cycles in Taxes are artificially dampened. Before that year, income taxed in Prussia were raised according to a dynamic tax smoothing formula that averaged taxable income over two and sometimes three years. (Hettlage 1984). As a result, tax revenues are a time-varying moving average of past realizations of the tax base. In a major tax

[11]For completeness we show also the results for Output, although it comes in real terms. A discussion follows further below.

reform in 1891, this system was abolished, and the "Taxes" series reflects annual income more reliably after that date, leading to more pronounced cycles.

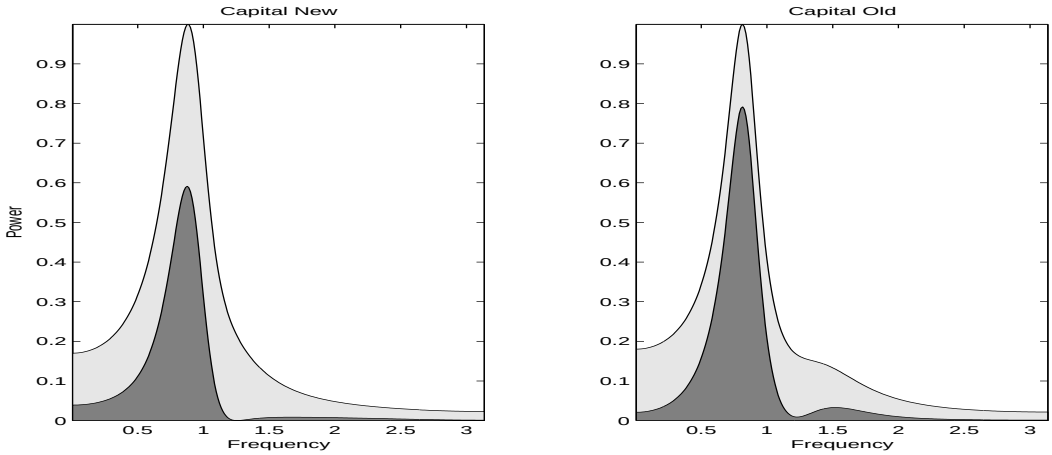

Figure 7: Share of variance of capital stock series explained by Ronge's stock market index.

We also note that the stock market does not explain the corrected Expenditure series as well as the original one. This applies also to Income, which at least is not explained significantly better after correction. Both corrections are based on the new capital stock estimate of Burhop and Wolff (forthcoming). They introduced an improved method extrapolating the Baden capital stock from Schremmer (1987) to Germany, trying to account for regional differences in industrial development. This does not seem to have improved the cyclical properties of the new capital stock series (see Figure 7). Explained variance over the 3-10 year is only 28 percent for the new capital stock series, but 40 percent for the old one. Thus, series that depend on the new capital stock are likely to have worse cyclical properties than their uncorrected counterparts. Evidently, the correction method applied by Burhop and Wolff (forthcoming) needs further improvement.

Since Income is found to be the series being closest to the financial market benchmark, we investigate this series more closely. It consists of capital income and labor income (in constructing this series, Hoffmann (1965, p. 510) assumed foreign incomes to be zero). Which of these subseries contributes most to the good cyclical properties of Income? The corrections applied to Income by Burhop and Wolff (forthcoming) left the wage and employment series unchanged but did affect both the capital stock and the return series. We have already seen that their correction to the capital stock series has, if anything, worsened its cyclical characteristics compared to the financial market benchmark. As regards returns on capital, Hoffmann (1965, p. 502) did not attempt to estimate rates of return at all but simply inserted

a constant. Burhop and Wolff (forthcoming) instead propose a series that proxies firms' profits by dividends, from which they obtain a series with pronounced cycles.

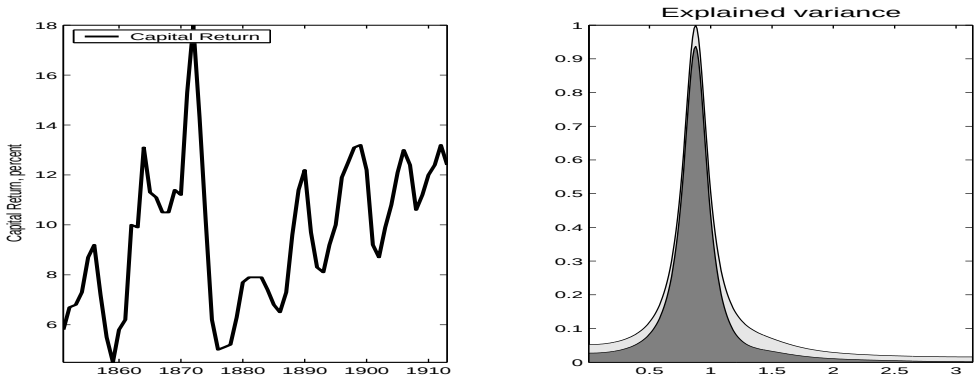

Figure 8: Burhop and Wolff's (forthcoming) return series and the variance explained by Ronge's stock market index.

Figure 8 shows the cyclical behavior of the new return series. With our default model specification, 65 percent of the variance are explained by the stock market.

This result is hardly surprising, as the return series was derived from dividends. With our research strategy it must perform well by construction, and therefore contains no information for our purpose.

The construction of the wage series, on the other hand, is not connected to the stock market. It was calculated from social security statistics collected in seven single years between 1884 and 1914, which are interpolated by daily wages in the grand duchy of Baden. For this reason, there is no a priori reason to assume the cyclical properties of Wages to be particularly good. However, we find the coherence between Ronge's stock market index and Hoffmann's wage series to be rather high.

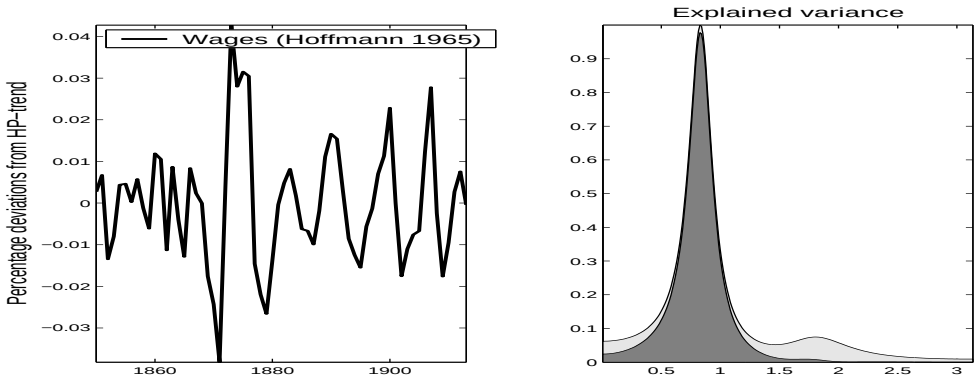

Figure 9: Hoffmann's (1965) wages series and the variance share explained by Ronge's stock market index.

As the Figure 12 indicates, about 70 percent of the variance in Wages is in fact explained by the stock market. The explanatory power of the financial market benchmark for wages is thus even higher than for Returns, although the latter is connected to the stock market index by construction, while the former is not.

Drawing the results of this section together, we find the comovement of the Expenditure, Taxes, and Income estimates of NNP with the stock market to be only marginally satisfactory. We do find, however, that there is strong coherence between Wages, i.e. Hoffmann's (1965) estimate of the aggregate wage bill, and the financial market. Since Wages are constructed independently from financial data, but have similar cyclical properties, we conclude that they should be investigated more closely for business cycle dating.

5.3 Nominal Indicators and Real Business Cycles

Before finally proceeding to the business cycle chronology, we have to make sure that we are not only talking about price changes, since both Wages and stock prices are denoted in nominal terms here. Recall that we decided to look at nominal series, because the quality of the various deflated NNP estimates is distorted by our insufficient knowledge about the correct price information contained in the nominal data. Thus our strategy was to look at nominal series first and then see afterwards if the cyclical information in these series is due to price fluctuations or to "real" fluctuations on business activity.

To do this, we proceed in two steps. First, we assess the comovement of various different price indices with our nominal series. Being aware that none of the given indices reflects the behavior of the price level correctly, we compare across three indices: Hoffmann's (1965) price index, wholesale price index of Jacobs and Richter (1935), and an index proposed by Ronge (2002) to deflate his stock price index. We find that prices seem to drive around 50–60 percent of the stock market's variation, and roughly 30–40 percent of the variation of Wages (Table 2). We also looked at the share of explained variance that is due to cycles of the same frequency and is *in phase*, i.e. contemporaneous. The variance by Wages that is explained by prices is almost entirely *in phase*, whereas the explained variance of the stock price index is not, but shifted in time by 2–3 years (Table 2 and Figure 10).[12]

Second, comparing our nominal series to typical business cycle indicators for the

[12]This has implications for the debate about RBC models and whether or not real wages are procyclical, see e.g. Christiano and Eichenbaum (1992). We find that a significant percentage of the cyclical behavior of wages at the relevant frequency is explained by contemporaneous price fluctuations. Still, when we deflate Wages, the result is not a flat series, but one with a cyclical time-series behavior that neither resembles the stock price index nor any price index.)

	Stock Market (Ronge 2002)					
Prices	Hoffm.		Ronge		J.&R.	
	EV	*in phase*	EV	*in phase*	EV	*in phase*
HP, 3-10 y.	62%	6%	48%	24%	58%	15%
HP, 7-10 y.	26%	0.3%	12%	6%	20%	0.1%
BK, 3-10 y.	54%	4%	36%	20%	50%	5%
BK, 7-10 y.	27%	0.2%	20%	16%	26%	0.05%
	Wages (Hoffmann 1965)					
Prices	Hoffm.		Ronge		J.&R.	
	EV	*in phase*	EV	*in phase*	EV	*in phase*
HP, 3-10 y.	38%	94%	53%	83%	29%	86%
HP, 7-10 y.	13%	92%	22%	93%	10%	80%
BK, 3-10 y.	32%	95%	34%	73%	24%	79%
BK, 7-10 y.	14%	93%	19%	92%	11%	69%

EV: Explained variance, HP: Hodrick-Prescott (6.25)

BK: modified Baxter-King (K=3, 2-15 years band), VAR(3)

Table 2: Variance explained of nominal stock prices and nominal wages by various price indices.

19th century we find that nominal stock prices are driven by real business cycle indicators as well as by price movements. The same accounts for wages, although the level of explanation is slightly lower for wages.

Table 3 shows that our indicators explain between 44 and 52 percent of stock price movements, and 33 to 42 percent of wage movements. Corroborating evidence may be obtained from looking at the behavior of these indicators in the time domain. Figure 11 below shows that both turning points as well as amplitudes of the volume indicators are reflected well in stock prices. Note that the stock market leads real indicators by one to two years.

An interesting finding here is that steel and iron production have around 30 percent variance *in phase* with the stock price index, whereas that number is close to zero for coal production and railway transport. While the share of *in phase* common fluctuation of steel and iron production with wages is about the same as with stock prices, a major difference occurs for coal production and railway transport: Their common variation is almost totally *in phase* with wages, while being *out of phase* with stock prices.

Thus, considering that stock prices are a leading indicator and wages a lagging one, we observe in our data that steel and iron production on the one hand and coal

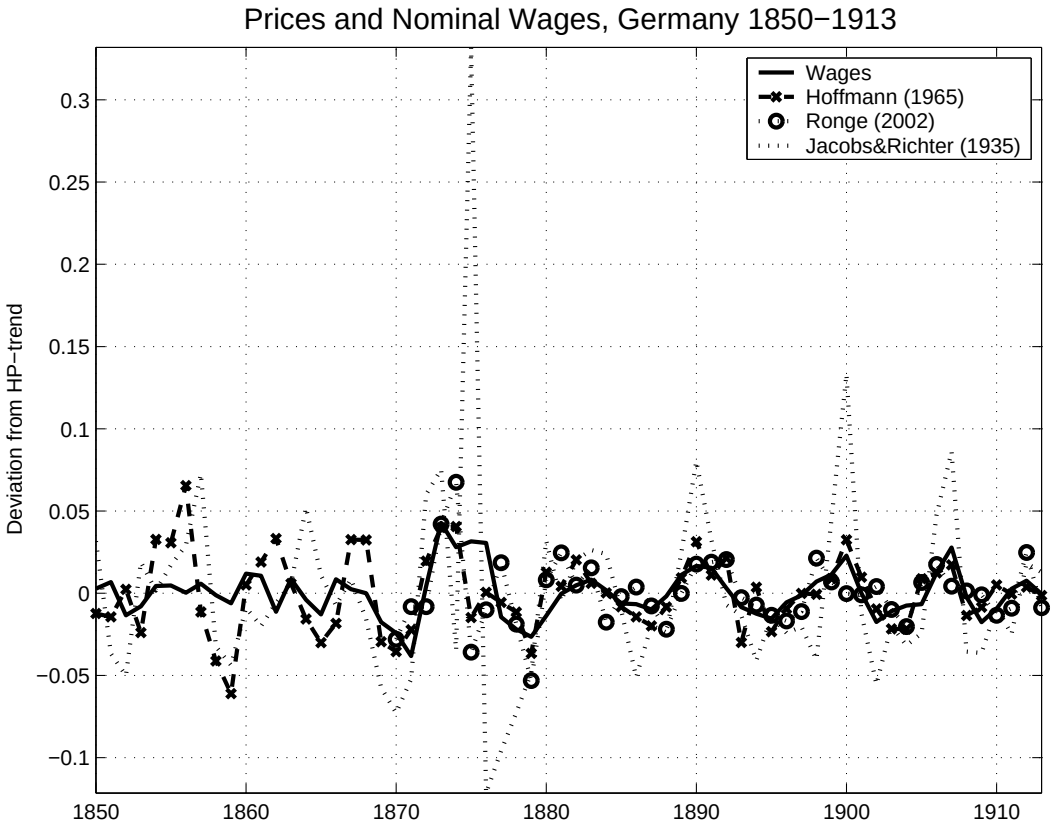

Figure 10: Hoffmann's (1965) wages series and three price indices

production and railroad transport where not *in phase* which each other. It seems that steel and iron production were rather coincident with the current state of the economy, while coal production followed with some lag.[13]

We also checked how much of Hoffmann's (1965) Output series is explained by the real indicators we use. It turns out that less than a third of the variation in Output is captured by the real indicator's (Table 4). Evidently, there seem to be additional sources of cyclical variation in Output that are not accounted for by either the stock market or the real indicators.

Summing up, we find that around half of the variation of the stock prices we look at is not driven by prices, but reflects real movements. Additionally, there is a time shift between stock prices and the general price level. Wages are in phase with the price level, but 30–40 percent of the variation in the wage series are explained by real indicators, which is more than Hoffmann's (1965) Output series, although it contains no price information. We therefore appear to have found a way to bypass

[13]We could argue that this is related to the vertical relation of coal production, railway transport and iron and steel production: Demand shocks could have driven the production of steel and iron, which then spurred coal production and railway transport.

	Stock Market (Ronge 2002)							
Real Ind.	Steel		Railway		Coal.		Iron	
	EV	*in phase*	EV	*in phase*	EV	*in phase*	EV	*in phase*
HP, 3-10 y.	48%	30%	68%	5%	44%	0.6%	52%	31%
HP, 7-10 y.	24%	31%	24%	4%	16%	0.3%	19%	31%
BK, 3-10 y.	48%	37%	54%	11%	42%	2%	44%	33%
BK, 7-10 y.	32%	34%	33%	3%	28%	0.2%	28%	29%
	Wages (Hoffmann 1965)							
Real Ind.	Steel		Railway		Coal.		Iron	
	EV	*in phase*	EV	*in phase*	EV	*in phase*	EV	*in phase*
HP, 3-10 y.	42%	41%	34%	83%	33%	87%	40%	43%
HP, 7-10 y.	30%	31%	15%	74%	14%	86%	21%	19%
BK, 3-10 y.	31%	38%	25%	89%	29%	88%	34%	47%
BK, 7-10 y.	23%	30%	12%	80%	11%	75%	17%	21%

EV: Explained variance, HP: Hodrick-Prescott (6.25)

BK: modified Baxter-King (K=3, 2-15 years band), VAR(3)

Table 3: Variance explained of nominal stock prices and nominal wages by various real indicators.

the problems in business cycle dating arising from incorrect price indices. We conclude that nominal indicators, although containing price information, include more information about the correct dating of the German pre-war business cycle than do incorrectly deflated national income and product series.

5.4 The Business Cycle Chronology, 1870–1914

We begin this section by plotting wages and Ronge's stock market index along the time axis (Figure 12).

Note that not only do wages and the stock market share a similar cyclical structure in the frequency domain, but they also exhibit a very similar cyclical pattern in the time domain. What matters here is not the amplitude of the cycles but rather the phase of its turning points. In order to make sure that this is not a figment of the data, we repeated the above exercise for Baxter-King filtered series and also include Eube's (1988) index (Figure 13).

In Figure 13 there is no major deviation from the predominant pattern: Stock markets and wages moved mainly in the same direction, and stocks precede wages by roughly one year.[14] This appears to reflect the blue chip nature of Ronge's index,

[14]Differences appear in the volatility of the series. The HP-filtered plot with Ronge's (2002)

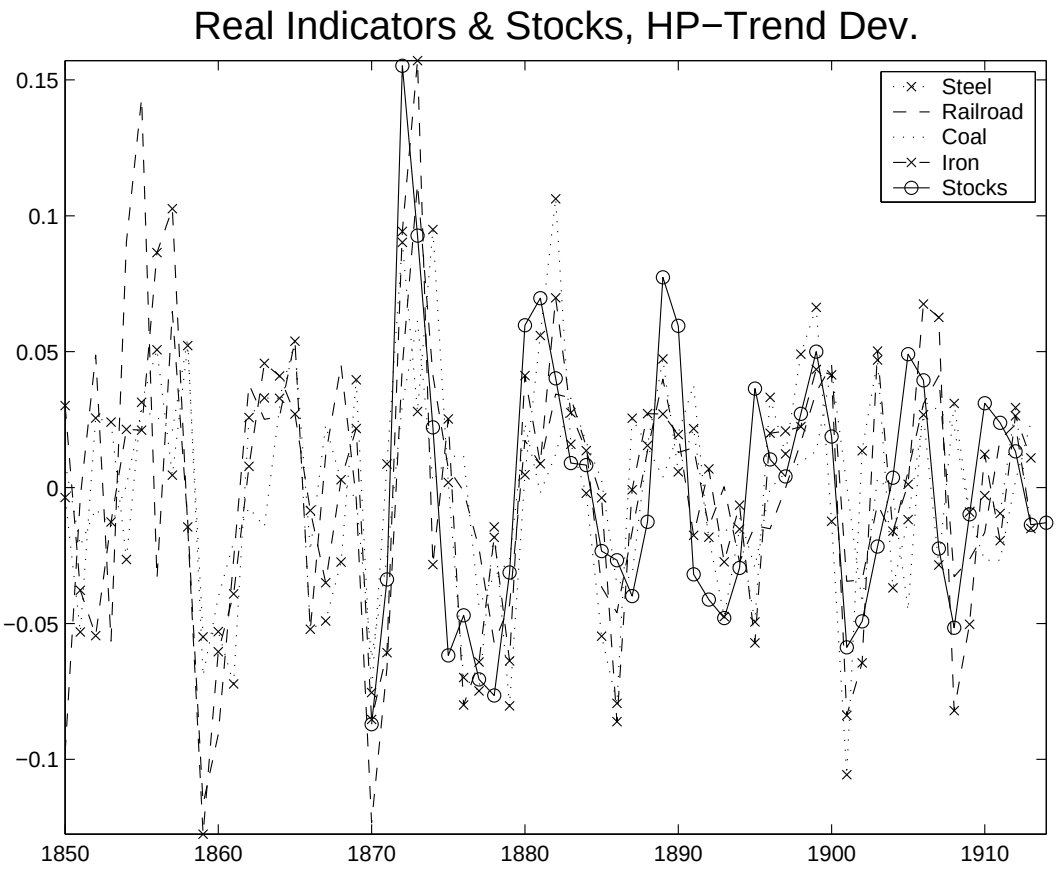

Figure 11: Ronge's (2002) stock prices and four real indicators.

as well as the exclusion of major railway stocks from the broader Eube index (see Section 3.2).

The next step is to compare Ronge's stock market index with established business cycle dating schemes and the new scheme proposed by Burhop and Wolff (forthcoming). The next figure plots the stock market index against the NBER reference Cycle for Germany, an influential dating scheme by Spiethoff (1955), and Burhop and Wolff's "Compromise"-series. The evidence suggests that the indicator-based dating procedures are in line with the turning points suggested by the stock market index and the Wage series, but differ from to the national accounting exercise of Burhop and Wolff (forthcoming) (see Table 5).

Except for the additional NBER cycle of 1904–1907 and the last peak before World War I, all peaks and troughs in Ronge/NBER occur at the same year plus/minus one year, which is very close for annual data. Ronge's (2002) stock market index seems to have a slight tendency to lead the NBER reference dates. Spiethoff

stock market index exhibits a particularly sharp upswing during the *Gründerzeit* boom of the 1870s (15%) compared to the other plots (∼8%).

	Output (B&W, forthcoming)				Output (Hoffmann, 1965)			
	Steel	Railway	Coal	Pig Iron	Steel	Railway	Coal	Pig Iron
HP, 3-10 y.	23%	21%	28%	34%	30%	26%	29%	46%
HP, 7-10 y.	6%	5%	5%	9%	8%	7%	7%	12%
BK, 3-10 y.	24%	17%	24%	32%	32%	24%	26%	44%
BK, 7-10 y.	6%	4%	4%	7%	8%	7%	5%	10%

HP: Hodrick-Prescott (6.25), BK: modified Baxter-King (K=3, 2-15 years band), VAR(3)

Table 4: Variance explained of Output (corrected and original) by real business cycle indicators.

(1955) finds an additional trough in 1883/84 and a peak in 1906/07, which is two years later than Ronge and NBER. He also finds a peak directly before the war in 1912/13.

Our results indicate that two forces might be at work in generating this result. On the one hand, Burhop and Wolff's Compromise estimate is the result of averaging series that are partly counter-cyclical to each other or shifted in time. On the other, as stated above, some of the series entering the Compromise estimate of Burhop and Wolff exhibit spurious volatility, which appears to carry over to their average series.

At the same time, the comparison of our results for the stock market to the NBER reference cycle shows a striking similarity, which can be understood as a confirmation of the indicator method for 19th century business cycle dating, as opposed to the national accounting approach.

It remains to trace the cyclical behavior of Hoffmann's Wages series over time. Bry (1960) reports evidence of wages lagging the business cycle.[15] He explains the delay by an observation lag of business cycle conditions, and the lags in the wage series resulting from collective bargaining between employers and workers. However, a lagged response of wages to the cycle is also consistent with the stochastic neoclassical growth model.

When plotting Hoffmann's (1965) wage series against one of Bry's (1960) most prominent wage series, hourly wage rates for hewers and haulers from the city of Dortmund, we find a high similarity between those series (69% explained variance), and no evidence of a phase shift (Figure 14). Both series are shifted by one or two years relative to Ronge's (2002) index and the NBER's reference turning points. Thus we should look for the "true" business cycle turning points between Ronge's index (a leading indicator) and Hoffmann's average wages (a lagging indicator). If we disregard the slight tendency of the stock market to precede the reference cycle, our

[15]Earnings seem to lag behind the business cycle less than wages (Bry 1960, pp. 139ff)

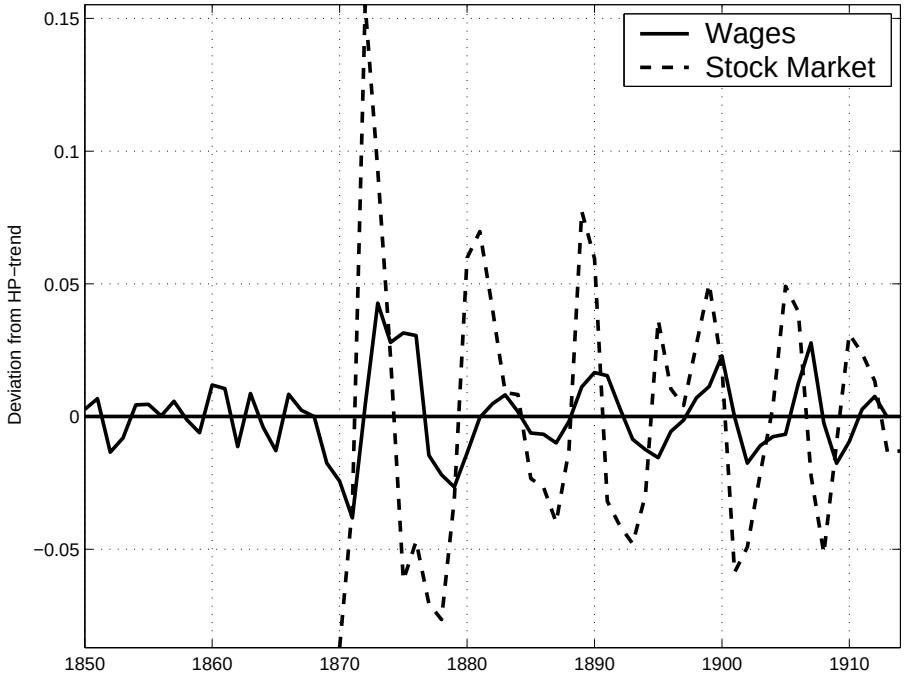

Figure 12: The cyclical behavior of Hoffmann's (1965) wages series and Ronge's stock market index in the time domain.

chronology moves even closer to the NBER reference points. Except for the troughs in 1871 and 1887, our results then fully confirm the NBER dating. The stock market peak of 1910 should then probably be substituted by a later date, since wages peak only in 1912. Table 6 contains the dating which follows from considering wages and the stock market.

The results of this section indicate that there is little, if any need to rewrite the business cycle chronology of Germany in the late 19th and early 20th century. Quite on the contrary, we are broadly able to reconfirm the traditional business cycle dating by the NBER and Spiethoff. What we can clearly rule out, however, is a tendency in parts of the recent literature to question the real effects of the *Gründerzeit/Gründerkrise* boom and bust of the 1870s on national product (Burhop and Wolff 2002). This view was informed by the deflated "Taxes" estimate of national income. However, we find robust evidence that the deflated "Taxes" series of national income suffers from spurious volatility, induced by the price deflator. Therefore, the cyclical information of this series can largely be dismissed as a figment of the data. Looking again at the various different nominal estimates of national income and product, the traditional business cycle of the 1870s reappears and is alive and well.

However, we are unable to revive the "Great Depression" of the late 19th century, an older long-swing hypothesis of a downturn between 1873-1896 that has already

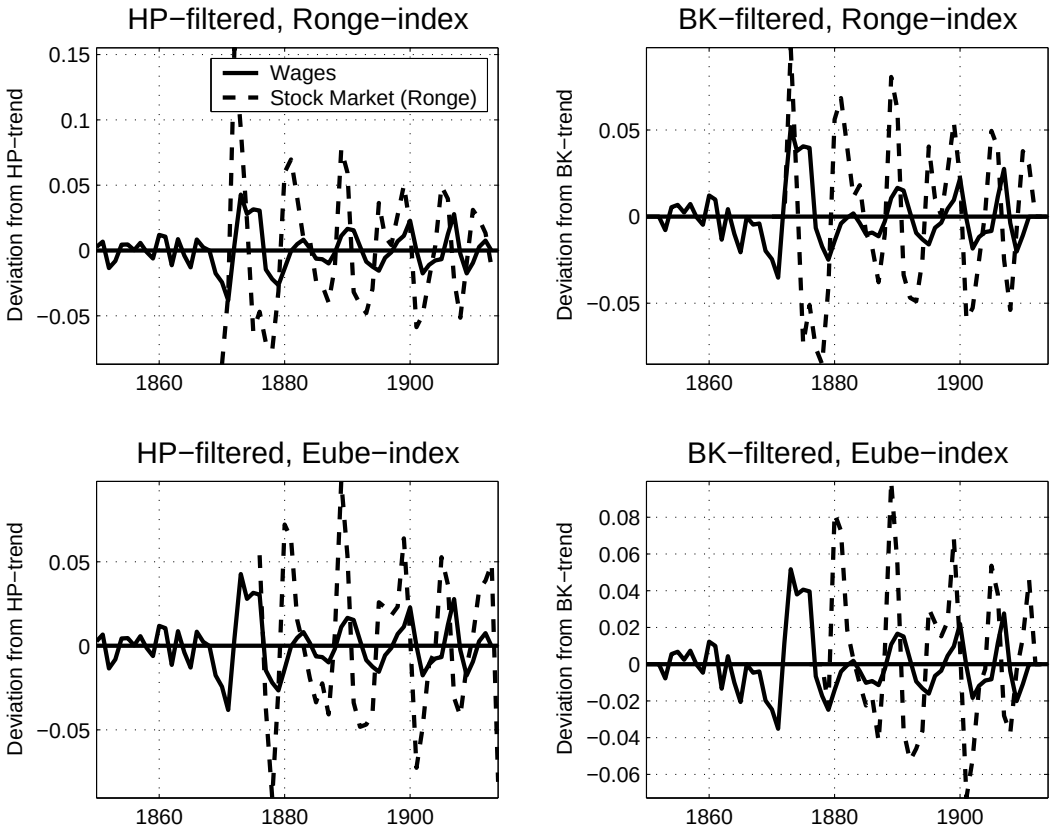

Figure 13: Hoffmann's (1965) wages series and the stock market indices of Ronge and Eube, HP and BK filtered.

be proclaimed dead by e.g. Spree (1978). There seems to be no resurrection of the Great Depression from our data.

6 Conclusions

Business cycle analysis for the 19th century with national accounting methods generally suffers from a weak data base and often inadequate statistical methods. As a result, alternative estimates of doubtful reliability lead to conflicting business cycle chronologies. In this paper, we examine the comovement of financial markets and national income for a number of rivaling series for Germany, applying spectral analysis. Under the efficient capital market hypothesis, there should be tight comovement between stock markets and the real economy, expressed in the frequency domain by high coherency between the power spectra. We employ coherency with financial markets as a selection device between the rivaling income series, and construct a new business cycle chronology for Germany between 1850 and 1913.

We find that the real series provided by Hoffmann (1965) and Hoffmann and

	Ronge (2002)		NBER (1946)		Spiethoff (1955)		B&W (forthcoming)	
	Trough	Peak	Trough	Peak	Trough	Peak	Trough	Peak
1	1871	1872	1870	1872	–	1872/73	1870/71	1872
2	1878	1881	1878	1882	1878/79	1881/82	1880	1874
3	1887	1889	1886	1890	1883/84	1889/90	1891	1888/89
4	1893	1899	1894	1900	1893/94	1899/00	1894	1898
5	1902	1904	1902	1903	1901/02	1906/07	1901	1907/08
6	–	–	1904	1907	–	–	–	–
7	1908	1910	1908	1913	1908/09	1912/13	1910	–

NBER as cited in Bry (1960,pp. 474f)

Spiethoff's dating procedure adapted for comparison: Peaks between slumps and booms, troughs between booms and slumps.

Compromise from Burhop and Wolff (forthcoming). They report troughs also in 1873, 1877, 1886/87, 1906, and peaks in 1874, 1878, 1883/84, 1893, and 1905, but with lower intensity.

Table 5: Comparison of business cycle dating for Germany, 1870-1913.

	1	2	3	4	5	6
Trough	1871	1878	1887	1894	1902	1908
Peak	1873	1882	1890	1900	1905/6	1911

Table 6: Business cycle dating for Germany, 1870-1913.

Müller (1959) suffer strongly from the deflating procedure. We therefore propose to look at nominal series. Among these, Hoffmann's (1965) Income series has the highest share of variance explained by a representative stock market index. Its subcomponent, an average wage series for Germany, exhibits surprisingly high coherency with the stock market. We show that the same property obtains for an alternative wage series from Bry (1960), which cover a wider set of industries than the series reported by Hoffmann (1965).

Using those series to date business cycle, we are able to confirm the traditional views for Germany from Burns' and Mitchell's (1946) NBER chronology, as well as those of Spiethoff (1955). This also implies that we discard later interpretations that have suggested different chronologies. Among our main findings is the reappearance of both *Gründerzeit* and *Gründerkrise*, the boom and bust of the 1870s, in the income and output data. On the other hand, we are unable to resuscitate the *Great Depression* of the 1880s, which is absent from any of the series we examined.

Our findings have potential implications for the methodology of historical business cycle research. We add to a small but growing literature that foregoes recon-

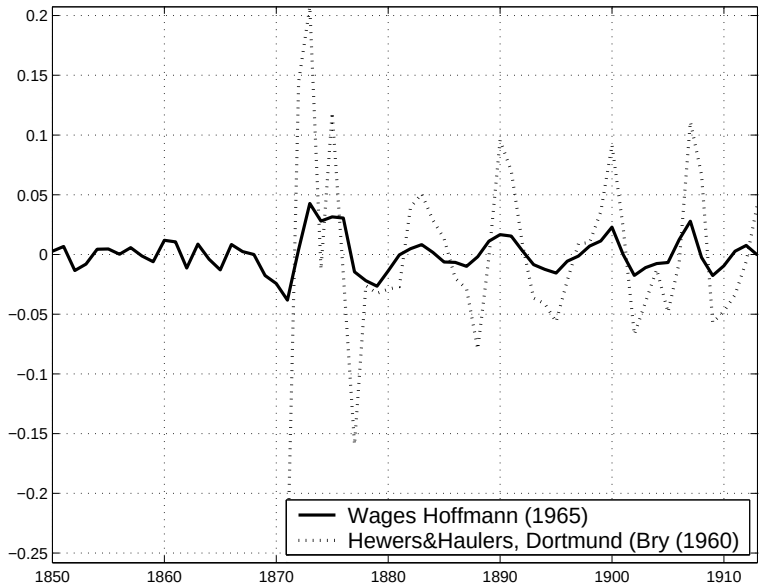

Figure 14: Hoffmann's (1965) wages series and Bry's (1960) hourly wage rates for hewers and haulers, Dortmund.

structed national account data in favor of the higher information content in real time price data. In a companion paper Sarferaz and Uebele (unpublished) go further by employing dynamic factor models to reconstruct the business cycle chronology for Germany, further confirming the results of the present paper.

Our methodology also lends itself to application for other countries, and may help to shed further light on long-standing debates about business cycle dating and frequency.

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