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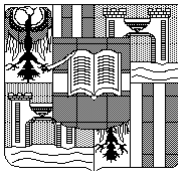
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The Austrian Business Cycle – A Characterization

by

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The Austrian Business Cycle – A Characterization

Introduction

Economies constantly undergo significant cyclical variations of distinct pattern and origin. In duration, business cycles vary from more than one to ten or twelve years, and comprise a boom, or expansionary phase, followed by a recession, or contractionary phase. Such cycles recur at unpredictable intervals and do not last for a fixed length of time. Recessions are characterized by high unemployment and low productivity with highly asymmetric short but sharper cycles than expansions.

The purpose of this paper is to provide an overall picture of the Austrian business cycle covering the period 1970 until 2004 by studying the cycle's "stylized facts" in terms of volatility, co-movements and persistence. The notion of stylized facts stems from the renowned work of Burns and Mitchell (1946) intending to provide and interpret model-free observations of macroeconomic variables' behavior. Additionally potential hypotheses as to the source of observed cycles will be tested, pointing at the significant role supply-side shocks like technology play in triggering observed business cycles.

This paper is organized as follows: Section I describes the methodology applied to extract the cyclical component from observed macroeconomic data. Section II gives a brief description of business cycle regularities observed in industrialized countries, while section III applies the empirical test to the economy case Austria and discusses the results on the basis of the data's second moments. Section IV attempts to identify potential sources of observed cycles, focusing on prices and the real wage rate as discriminatory factors. A discussion of the baseline Real Business Cycle Model's basic characteristics as well as resemblances with the observed data represents the focal points of section V while section VI concludes.

I. Methodology – the Hodrick-Prescott Filter

The study of business cycle starts with the process of detrending key macroeconomic variables since second moments of time series variables, i.e. volatility, co-movement and persistence can only be applied to stationary stochastic processes. The literature offers numerous detrending or equivalently, smoothing procedures, including first differencing, band-pass filters (Baxter/King (1999)) and Hodrick-Prescott (HP) filters (Hodrick/Prescott (1997)). The latter, as a two-sided symmetric moving average filter, is the most frequently applied trend-cycle decomposition technique due to its simple mechanical and judgmental-free implementation and the resemblances with actual business cycle movements. However, its shortcomings are also highlighted in the literature. In that respect, Cogley and Nason (1995) and Harvey and Jaeger (1993) argue that the Hodrick-Prescott filter might cause spurious cycles in the case of difference-stationary data, that the filter might create most of the cycles

in the data or that the filter is only optimal in special cases, as pointed out by King and Rebelo (1993). However, Ravn and Uhlig (1997) hypothesize that the filter will remain the standard method for detrending for a long time to come since “the HP-filter has withstood the test of time and the fire of discussion remarkably well”.

According to Hodrick and Prescott (1997) observed time series y_t are the sum of cyclical y_t^c and growth components y_t^g with the latter varying smoothly over time. Methodologically, this observation can be represented as follows:

$$y_t = y_t^c + y_t^g \quad \text{for } t = 1, \dots, T$$

Assuming that the smoothness of growth can be measured by the sum of squares of its second-order differences, the growth components can be calculated by minimizing the following least squares problem:

$$\min_{\{y_t^g\}_{t=0}^T} \left\{ \sum_{t=1}^T (y_t - y_t^g)^2 + \lambda \left[(y_{t+1}^g - y_t^g) - (y_t^g - y_{t-1}^g) \right]^2 \right\}$$

The above problem consists of two components. The first component can be interpreted as a measure of fitness and becomes minimal for $y_t = y_t^g$, while the second component, as a moving-average representation, can be viewed as a measure of smoothness and becomes minimal for invariable growth in y_t^g , i.e. linear growth over time. The parameter λ is a positive number representing a penalty on growth variability, with higher values resulting in smoother growth components and consequently more erratic cyclical components. After Burns' and Mitchell's influential work on pre-second world war U.S. business cycle regularities, the length of cycles was widely accepted to vary between 1 ½ and 8 years. Hence, based on their observations filters are specified to cut off components of higher or lower frequencies in order to capture better the cyclical component. For quarterly data, the convention is to set λ equal to 1,600.

However, an unreflected application of a standardized smoothness parameter is unadvisable, particularly taking into account that the standard is based on outdated and country-specific business cycle observations. To that end, Pedersen (1998) stresses that the adoption of the Burns/Mitchell observation of 8-year cycles should be reconsidered, since the study covers the pre-world-war II period only while important characteristics of the classical cycles have changed in the US from the pre- to the post-war period along with structural and institutional changes in the economy. More importantly, their measure of the US cycles does not discriminate between economic growth and cyclical variations of time series hence their measure of the cycle duration from peak to peak is overstated. His analysis of 11 OECD countries (including the US) reveals that postwar cycles are

better described as covering six- year cycles at most, calling for a modification of the smoothness parameter λ to range between 310 and 340 for quarterly data.

Table 1 Augmented Dickey-Fuller Tests for different Lambdas

Variables	t-value	<i>p-value</i>	$\lambda = 100$ t-value	<i>p-value</i>	$\lambda = 25$ t-value	<i>p-value</i>	$\lambda = 6.25$ t-value	<i>p-value</i>
Real GDP	0.303	0.9764	-3.766*	0.0033	-4.431*	0.0003	-5.470*	0.0000
Real Government Expenditures	-1.564	0.4997	-1.922	0.3217	-3.391*	0.0113	-5.081*	0.0000
Real Private Consumption	-1.187	0.6790	-4.185*	0.0007	-5.091*	0.0000	-6.135*	0.0000
Real Investments	-0.507	0.8922	-4.141*	0.0008	-4.901*	0.0000	-5.831*	0.0000
Real Exports	4.131	1.0000	-3.571*	0.0063	-3.958*	0.0016	-4.864*	0.0000
Real Imports	2.713	1.0000	-3.928*	0.0018	-4.557*	0.0002	-5.411*	0.0000
Real Interest Rate	-2.238	0.1926	-6.245*	0.0000	-7.126*	0.0000	-7.827*	0.0000
CPI	-2.235	0.1937	-2.273	0.1809	-2.779	0.0613	-3.400*	0.0110
Inflation Rate	-1.485	0.5393	-4.353*	0.0004	-4.939*	0.0000	-5.880*	0.0000
Real Wage Rate	-4.406*	0.0003	-3.337*	0.0133	-3.477*	0.0086	-4.086*	0.0010
Capital Stock	13.673	1.0000	-2.877*	0.0481	-2.760	0.0642	-3.407*	0.0107
Money Supply	-0.451	0.9025	-4.420*	0.0003	-4.990*	0.0000	-5.737*	0.0000
Dependent Employment	-2.341	0.1591	-2.654	0.0823	-2.958*	0.0390	-3.662*	0.0047
Total Employment	-0.680	0.8534	-2.165	0.2191	-2.408	0.1394	-3.048*	0.0306
Labor Productivity	0.347	0.9782	-5.745*	0.0000	-6.110*	0.0000	-6.703*	0.0000

Source: Own Calculations

All regressors include a constant. The critical value at the 5 % significance level is -2.89 from Fuller (1976), indicated by an asterix.

As for annual data frequencies, different smoothness parameters are suggested by the literature. On the one hand, Backus and Kehoe (1992) in their study on business cycle properties of a cross-section of countries apply a smoothness parameter of 100, while, on the other, Correia et al (1992) and Cooley and Ohanian (1991) use a lambda of 400. Related to that, Ravn and Uhlig (1997) - in their study on the proper adjustment of filters to diverse data frequencies - suggest alternative smoothness parameters. Based on a graphical representation of different parameters for annual data to best replicate the conventionally applied parameter of λ of 1.600 for quarterly data, they recommend a smoothness parameter of 6.25 as the closest match.

With respect to the “optimal” choice of the smoothness parameter, since the filter eliminates the secular trend component, the cyclical component of the observed time series should be tested for stationarity to ensure any long term trend to be eliminated by the filter. To do this, the augmented Dickey-Fuller unit root test was first applied to all original data variables as shown in the first column of Table 1. With the exception of real wages, all variables appear non-stationary and call for detrending for further analysis. Columns 2, 4, 6 and 8 show the results of the augmented Dickey-Fuller tests for different λ s like 100, 25 and 6.25 and the respective p-value of significance and hence represent the rationale for choosing 6.25 for the analysis.

After detrending the series, basic characteristics can be inferred;

Volatility assesses the amplitude of fluctuations and indicates the magnitude of the variable's contribution, and its sensitivity, to aggregate fluctuations. This is measured by the standard deviation, where a low standard deviation implies the variable does not contribute much to aggregate fluctuations.

Co-movements with contemporaneous output series indicate the cyclicity of key macroeconomic variables like private consumption, investment, government expenditures, and money supply. These are measured by the correlation coefficients where positive, negative or near-zero coefficients point to pro-, counter-, and acyclicity, respectively.

Finally, **persistence** indicates the inertia in business cycles, particularly the cyclical component, and captures the length of observed fluctuations. This is measured by the first-order autocorrelation coefficient where a high coefficient implies a very persistent, i.e., long, economic fluctuation. Positive coefficients indicate that high values follow high values or low values follow low ones, whereas negative coefficients indicate reversals from high to low values or the reverse.

II Business Cycles in Industrialized Countries: A Brief Description

VOLATILITY. Business cycles in industrialized countries are found to cover a period of approximately six to eight years with high volatility in investment in consumer and producer durables and low one in private consumption. The most volatile expenditure category however is inventory investment. Employment also varies considerably over observed cycles but less than real GDP, while productivity as well as wages show comparably lower variation. The capital stock is found to show little volatility. Given different preferences, institutional set-ups, and war crisis, government expenditures reveal diverse behaviors across countries and are found to be either more or less variable than real national GDP (Fiorito/Kollintzas, 1994). In the same vein, money does not have a clear cut pattern but varies differently across countries and money stock definitions. Exports and imports are found to be more variable than consumption but less variable than investments. Finally, inflation exhibits high volatility.

CO-MOVEMENTS. For industrialized countries, King and Rebelo (1999) stress that most macroeconomic variables are procyclical with a particularly high degree of co-movement between aggregate output and total hours worked. Additionally, wages, government expenditures, and the capital stock seem to display no systematic cyclicity with aggregate output.

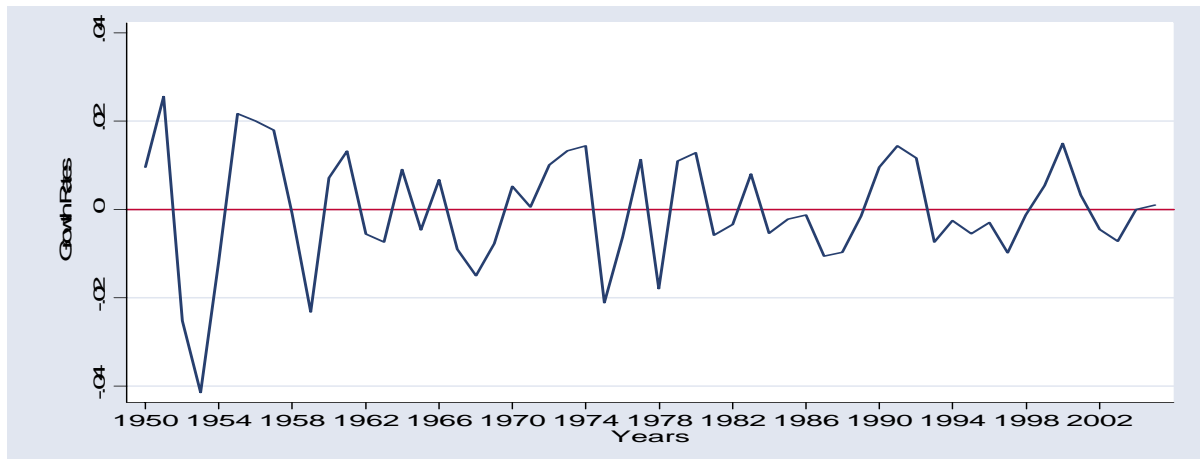
PERSISTENCE. Macroeconomic variables in industrialized countries display non-negligible persistence.

III Empirical Test: The Austrian Case

Figure 1 uses data from the Total Economy Database provided by the Conference Board and Groningen Growth and Development Centre (2006) and suggests that with the exception of the post-World-War II period of the 1950s, the Austrian business cycles move within a bandwidth of $\pm 2\%$

For the rest of the paper, the analysis avails of annual macroeconomic variables covering the period 1970 to 2004 from the Economic Outlook (ECO) database available on the WIFO database (the Austrian Economic Research Institute) and covers real gross domestic product (GDP), private consumption, government expenditures, investments, exports, imports, capital stock in the business sector, real money supply (M2), the consumer price index (CPI), the inflation rate calculated from the GDP-deflator, the real long-term interest rate deflated with the GDP-based inflation rate, total employment, total dependent employment, the real wage rate for the business sector deflated with CPI and labor productivity. Only real money supply, the real interest rate and the inflation rate cover shorter periods: 1970 to 1998 for real money supply and 1971 to 2004 for the real interest rate and the inflation rate. All real components are expressed in terms of 2000 prices.

Figure 1 Austrian Business Cycles, 1950-2004



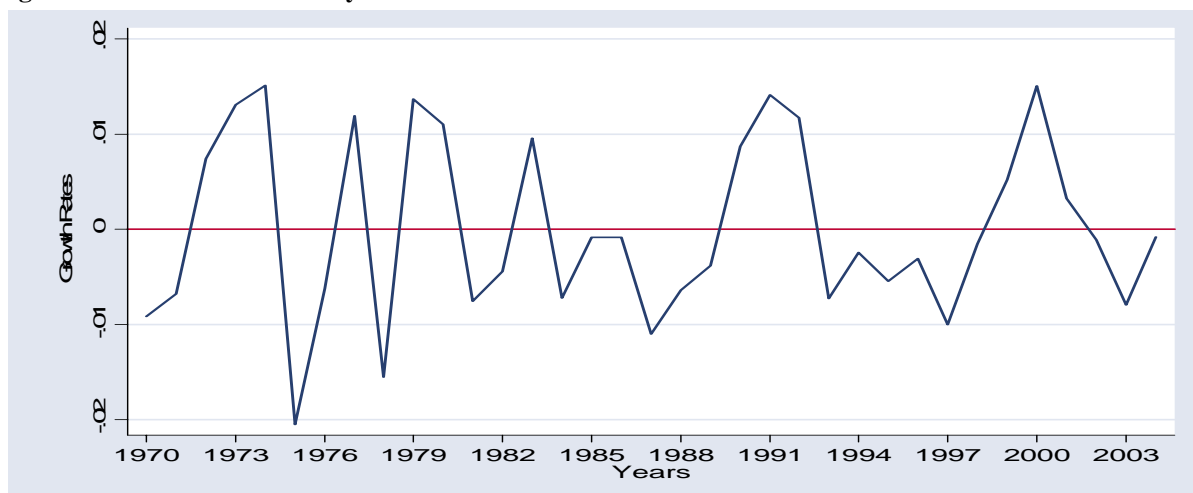
Source: GGCD-Data

In correspondence with the suggestions of Uhlig and Ravn (1997) paired with the Dickey-Fuller tests of stationarity for different smoothness parameters motivate λ to be set equal to 6.25 and the application of the Hodrick-Prescott filter procedure to decompose available time series. The application of alternative smoothness parameters and associated implications are discussed in the data appendix A.

Figure 2 gives a representation of the Austrian business cycles covering the period 1970 to 2004. While the 1970s appear to be dominated by the effects of the two oil price shocks in 1974 and 1978, starting in 1983a peak-to-peak duration analysis of observed cycles reveals two very similar cycles: One cycle covers the eight-year period from 1983 to 1991 with a recession in 1987. The other cycle

covers a nine-year period from 1991 to 2000, with a recession in 1997. Interestingly, the economy was on its way to economic recovery already when the rather severe recession of 1987 hit Austria. In correspondence with previous observations, recessions seem to be sharper but less deep.

Figure 2 Austrian Business Cycles - 1970-2004



Source: Own calculations

Volatility. Table 2 reports standard deviations of HP-filtered national expenditure components, as well as the real long-term interest rate, the consumer price index, the inflation rate, the capital stock, M2, dependent employment, total employment, the real wage rate and labor productivity. Among the national expenditure components, investment is the most volatile variable while government expenditures is the least volatile one. Relative volatility, defined as the ratio of a component's volatility to volatility of real GDP furthermore shows that with the exception of government expenditures, the capital stock, total as well as dependent employment and the real wage rate, all components have higher volatility than real GDP, with investments four times more volatile than real GDP.

The relatively high volatility of investments is typically associated with Keynes' famous assertion of "animal spirits" of investors – exogenous and perhaps self-fulfilling waves of optimism and pessimism. This also forms part of the widely accepted belief that investment bursts set off business cycles. Among the monetary and price variables, money supply M2 is two times more volatile than real GDP and CPI is equally volatile. Additionally, the inflation rate and the long-term interest rate represent the two most volatile monetary components with a 71-times and a 48-times higher volatility as compared to real GDP. As expected, the capital stock is the least volatile variable. Labor market specific variables all exhibit relatively low volatility with all but labor productivity revealing lower than GDP volatility. As to capital stock and employment, expensive adjustments in the major production inputs like capital and labor might be held responsible for the observed sluggish changes. After a decomposition of the whole period under investigation into two subperiods, one covering 1970 to 1983 and the other covering 1983 to 2004, it becomes apparent that for the first subperiod, with the

exception of the inflation rate, all variables depict higher volatility, while for the second subperiod, with the exception of exports, the inflation rate, total employment and labor productivity, all variables depict lower volatility than observed for the period as a whole. The relatively higher volatility of all variables during the first subperiods might be put down to the effects of the two oil-price shocks in the 1970s.

Table 2 Standard Deviation

Variables	No. of Obs.	Overall Period	Volatility relative to that of output	Subperiod 1970-1983	Volatility relative to that of output	Subperiod 1983-2004	Volatility relative to that of output
Real GDP	35	0.0095	1.00	0.0121	1.00	0.0078	1.00
Real Government Expenditures	35	0.0059	0.62	0.0063	0.53	0.0058	0.75
Real Private Consumption	35	0.0110	1.15	0.0140	1.16	0.0109	1.41
Real Investments	35	0.0411	4.32	0.0598	4.95	0.0256	3.30
Real Exports	35	0.0258	2.72	0.0246	2.04	0.0275	3.54
Real Imports	35	0.0299	3.15	0.0349	2.89	0.0267	3.45
Money Supply	29	0.0209	2.20	0.0281	2.33	0.0111	1.43
Real Interest Rate	34	0.4593	48.28	0.7449	61.70	0.1218	15.70
CPI	35	0.0092	1.00	0.0121	1.00	0.0069	0.89
Inflation Rate	34	0.6755	71.00	0.1625	13.46	0.8391	108.18
Capital Stock	35	0.0034	0.35	0.0038	0.32	0.0030	0.38
Total Employment	35	0.0047	0.50	0.0042	0.35	0.0052	0.67
Dependent Employment	35	0.0056	0.59	0.0062	0.51	0.0054	0.70
Real Wage Rate	35	0.0091	0.95	0.0091	0.75	0.0090	1.15
Labor Productivity	35	0.0108	1.14	0.0167	1.39	0.0056	0.72

Source: Own calculations

Co-Movements. Table 3 reports cross-correlations of national expenditure components, the real interest rate, CPI, the inflation rate, the capital stock, money supply, dependent employment, total employment, the real wage rate as well as labor productivity with output. With the exception of government expenditures, the inflation rate and money supply, all variables show strong and positive correlation with real GDP while the real interest rate and CPI depict strong and negative correlation with real GDP. Government expenditures, the inflation rate and money supply do not seem to reveal any significant cyclicity with real GDP.

A closer look at the periodical decomposition further reveals that with the exception of investments, imports, the real interest rate and CPI, money supply and labor productivity, all variables in the first subperiod show lower correlation with real GDP, while for the second subperiod government expenditures, private consumption, the inflation rate, the capital stock, dependent employment and total employment show higher correlation with real GDP than observed for the period as a whole. In the first period, only private consumption, investments, imports and labor productivity are

significantly and positively correlated with output while for the second period, private consumption, exports and imports, the capital stock, dependent as well as total employment, the real wage rate and labor productivity reveal positive significant correlation with real GDP.

Table 3 Correlation with real GDP

Variable	Overall Period t-value	Subperiod 1970-1983	Subperiod 1983-2004
Real Government Expenditures	0.1762	0.0778	0.3358
Real Private Consumption	0.6872*	0.6264*	0.7571*
Real Investments	0.7502*	0.8309*	0.3969
Real Exports	0.5135*	0.4508	0.5012*
Real Imports	0.6960*	0.7759*	0.5287*
Nominal Interest Rate	0.1375	-0.2799	0.5272*
Real Interest Rate	-0.3846*	-0.5333	0.1718
CPI	-0.4220*	-0.5104	-0.2871
Inflation Rate	0.2228	-0.0861	0.3464
Real Wage Rate	0.4080*	0.3877	0.4263*
Capital Stock	0.5028*	0.4545	0.5681*
Money Supply	-0.1438	-0.2902	0.3407
Dependent Employment	0.6110*	0.3993	0.7071*
Total Employment	0.5793*	0.2839	0.7472*
Labor Productivity	0.8705*	0.9798*	0.7062*

Source: Own calculations

Asterix denotes significant at 5 % level

Persistence. Table 4 shows the persistence of variables measured by the first order autocorrelation. The data illustrate fairly persistent variables with exports, CPI, the real wage rate, the capital stock and total employment as the most persistent macroeconomic variables for the overall period. With respect

Table 4 First-Order Autocorrelation

Variable	Overall Period	<i>p-values</i>	Subperiod 1970-1983	<i>p-values</i>	Subperiod 1983-2004	<i>p-values</i>
Real GDP	0.0478	0.6243	-0.1577	0.4201	0.3441	0.0003
Real Government Expenditures	0.1128	0.6457	-0.0013	0.2035	0.1919	0.6099
Real Private Consumption	-0.0626	0.6890	-0.1452	0.7289	0.0493	0.2212
Real Investments	-0.0301	0.6028	-0.0889	0.5210	0.1788	0.1378
Real Exports	0.1503	0.0137	-0.1234	0.2035	0.2781	0.3019
Real Imports	0.0443	0.1458	-0.1134	0.2361	0.2099	0.1131
Real Interest Rate	-0.1695	0.4085	-0.1569	0.1294	-0.3764	0.0590
CPI	0.4993	0.0000	0.4575	0.0020	0.5600	0.0002
Inflation Rate	-0.0541	0.9515	0.0111	0.2961	-0.0553	0.8550
Real Wage Rate	0.3898	0.0064	0.1944	0.0868	0.4835	0.1864
Capital Stock	0.4816	0.0003	0.2521	0.4072	0.6700	0.0000
Money Supply	-0.1169	0.4372	-0.1893	0.3153	0.1791	0.1240
Dependent Employment	0.4107	0.0791	0.1989	0.1855	0.5275	0.0234
Total Employment	0.5221	0.0000	0.1550	0.3333	0.6311	0.0001
Labor Productivity	-0.1574	0.3322	-0.1765	0.3130	0.0273	0.6529

Source: Own calculations

to real GDP, the periodical decomposition points at higher persistence in the second subperiod as opposed to the first and the overall period. During the first subperiod, only CPI reveals strong persistence, while for the second subperiod, CPI, the capital stock, total dependent and total employment show strong persistence.

IV Potential Sources of the Austrian Business Cycles

Over the past decade, considerable effort has been devoted to shedding light on the potential sources of business cycles by studying the price-output and inflation-output correlations, i.e. the cyclicity of prices and inflation. To that end, if supply shocks like terms of trade shocks, technology shocks or shocks due to extreme weather conditions are identified as the basic source, a negative price-output correlation should be observed. Conversely, if demand shocks like shocks to private or public consumption or monetary shocks represent the source of the business cycle, a positive price-output correlation should be identified. This can best be analyzed within a traditional AS-AD framework, where a shift of the supply curve (AS) along the negatively-sloped demand curve (AD) leads to countercyclical prices while a shift of the demand curve along the positively-sloped supply curve results in procyclical prices/inflation.

The real business cycle theory, as a purely supply side approach, and the traditional Keynesian theory, as a purely demand side approach, lead to different price-output correlations and therefore help discriminate between different economic schools. Traditionally, the Keynesian demand driven models focus on the inflation rate rather than the price level as the variable of interest so that a positive inflation output correlation emerges. In that respect, the real-business-cycle theory leads to countercyclical prices while the traditional Keynesian theory predicts procyclical inflation rates.

Empirical results on developed and developing countries however remain inconclusive as to the exact source of observed cycles.

Chadha/Prasad (1994), using quarterly data from the IMF's International Financial Statistics point at the countercyclicity of the price level for the G7 countries. However, this result does not carry over to the inflation-output correlation and no clear-cut inference about the source of the shock can be made.

Additionally, Kim et al. (2003) report fairly strong countercyclicity for prices for the G7 for the period covering 1960 to 1996 for data taken from IFS while Fiorito and Kollintzas (1994) show strong countercyclical prices for the G7 countries for quarterly data between 1960 and 1989.

Furthermore, describing historical properties of business cycles of a cross-section of countries for the prewar, interwar and postwar period, Backus and Kehoe (1992) report negative correlations of national inflation rates with real GDP for the postwar period for Australia, Canada, Denmark,

Germany, Italy, Japan, Norway, Sweden, the UK and the US and positive or mixed correlations with output for the prewar and interwar period, respectively.

With respect to price levels, all countries except Canada and Germany reveal negative correlations during the postwar period. For the prewar period, only Germany, Italy and Japan show negative correlations with output, while for the interwar period, only Denmark displays a negative output-price correlation. Hence, supply-led business cycles appear to be more prominent in the afterwar period while demand-side driven business cycles seem to be prevalent for the prewar period.

Additionally, Mendoza (1995) emphasizes that the term supply shock entails more than just technology shocks by showing that about 50 percent of overall output fluctuations for G7, as well as for developing countries, are due to shocks to terms of trade.

Table 5 Correlation of real GDP with detrended and contemporaneous Inflation and CPI

Lag	Panel A. Filtered Inflation and Output			Panel B. Filtered CPI and Output		
	Overall Period	Subperiod 1970-1983	Subperiod 1983-2004	Overall Period	Subperiod 1970-1983	Subperiod 1983-2004
1	0.1959	0.6249*	0.1993	0.0941	-0.0009	0.2498
0	0.2228	-0.0861	0.3464	-0.4220*	-0.5104	-0.2871
-1	-0.0111	-0.3392	0.0347	-0.4775*	-0.4612	-0.5071*

Source: Own calculations

Asterix denotes significant at 5 % level

Table 5 reports correlations between HP-filtered inflation and real output in panel A and correlations between HP-filtered prices with real output in panel B, all for contemporaneous real GDP as well as periods of one lead and lag each. Again, a periodical decomposition for both correlation analyses is conducted.

Panel A shows insignificant positive correlation of inflation with contemporaneous output for the overall period and second subperiod and insignificant negative correlation for the first subperiod. All in all, only the second subperiod shows a strong and significant positive correlation between inflation and output with inflation, leading output by one period. For the second subperiod, positive however insignificant inflation-output correlations dominate the picture, pointing at demand-side driven business cycle theories to play a rather insignificant role in triggering the Austrian business cycles.

For the period as a whole as well as both subperiods, panel B reports negative correlations between contemporary CPI and GDP with a significant negative correlation only for the overall period. This together with the countercyclical price-output relations for Austria between 1964 and 1990 by Brandner and Neusser (199?) supports predictions of supply-side led theories of economic fluctuations for Austria, like the real business cycle approach. Additionally, the lead-lag analysis points at prices countercyclically lagging real output by one year.

Moreover, apart from the price-output correlation as indicative factor to discriminate between traditional Keynesian versus real business cycle models of economic fluctuations, correlation of real wages with real GDP represent an additional discriminatory factor. In that respect, traditional Keynesian models of business cycles with sticky nominal wages predict countercyclical real wages while the real business cycle tradition predicts procyclical wages with procyclical labor productivity determining real wages.

Table 6 Correlation of real GDP with detrended and contemporaneous real wages

Lag	Filtered Real Wage and Output		
	Overall Period	Subperiod 1970-1983	Subperiod 1983-2004
1	0.3831*	0.6152*	0.2679
0	0.4080*	0.3877	0.4263*
-1	0.0881	-0.0250	0.1789

Source: Own calculations

Asterix denotes significant at 5 % level

The analysis further reveals that for the Austrian economy for the overall period, real wages exhibit significant procyclical correlation with contemporaneous real GDP as well as lagged real GDP, further emphasizing supply-side led shocks as a source of business cycles in Austria.

A periodical breakdown of correlations shows a significant positive relationship between lagged real GDP and real wages for the period 1970 to 1983 and a significantly positive contemporaneous correlation between said variables for the period 1983 to 2004.

V. Resemblances of the Findings with the Baseline Real Business Cycle Model

The baseline Real Business Cycle Model is conceptualized as a one sector, closed economy case with external, sector-neutral technological shocks initiating economic fluctuations and rational, maximizing agents optimally responding to said shocks and hence, no significant role attributed to the state within the realm of (fiscal or monetary) stabilization policy. In that respect, representative consumers are characterized as maximizing expected lifetime utility from consumption of goods and services c_t (as consumption per household member) as well as leisure $1 - l_t$,

$$E_t U = E_t \sum_{t=0}^{\infty} e^{-\rho t} u(c_t, 1 - l_t) \frac{N_t}{H},$$

with $u(\bullet)$ as the instantaneous utility function of the representative household member, often characterized as log-linear in two arguments: $u_t = \ln c_t + b \ln(1 - l_t)$, ρ as the discount rate and N_t and H as population and the number of households, respectively. At the same time consumers are expected to supply labor and rent out capital on competitive markets, with real wages and real interest

rate determined by their marginal products. Additionally, population is expected to exhibit constant growth with $N_t = N_0 e^{\eta t}$ with the annual growth rate given by η .

Representative producers are expected to maximize profits given the neoclassical production technology

$$Y_t = K_t^\alpha (A_t L_t)^{1-\alpha},$$

with capital (K), labor-augmenting technology (A) and labor (L) as inputs to production.

Technology is assumed to evolve according to the following stochastic process: $\ln A_t = \bar{A} + g_t + \tilde{A}_t$, where \bar{A} is the average level of technology, g_t is the rate of technological progress and \tilde{A}_t captures the effect of a random technology shock. Said shocks are modeled as first-order autoregressive processes: $\tilde{A}_t = \rho_A \tilde{A}_{t-1} + \varepsilon_{A,t}$, with ρ_A as the intertemporal transmission factor with $-1 < \rho_A < 1$ and the uncorrelated white noise shock $\varepsilon_{A,t}$ with zero mean ($E_t \varepsilon_{A,t} = 0$). With $-1 < \rho_A < 1$ the effect of the shock eventually dissipates.

Consumers have two decision variables to take into account when maximizing their lifetime utility. With respect to labor l_t , an intertemporal decision rule emerges with consumers continuously deciding over the exact amount of labor to be supplied depending on the relative real wage rate in period 2 relative to the one in period 1:

$$\frac{1 - l_1}{1 - l_2} = \frac{1}{e^{-\rho t} (1 + r)} \frac{w_2}{w_1}.$$

Hence, with an increase in the real wage rate in period 1, supply of labor also increases in said period. And with higher income (approximated by a higher real wage rate and higher labor supply) consumption also increases in period 1. Additionally, with an increase in the real interest rate, first period labor supply also rises relative to second period labor supply, with augmented income transferred to bank accounts for reasons of savings to be lent out to producers for investments.

With respect to consumption under uncertainty, the problem of intertemporal redistribution of foregone consumption arises, captured by the following equation

$$\frac{1}{c_t} = e^{-\rho t} E_t \left[\frac{1}{c_{t+1}} (1 + r_{t+1}) \right].$$

And with the product of two expectation variables given by the product of their expectations plus their covariance, intertemporal consumption is determined by

$$\frac{1}{c_t} = e^{-\rho} \left(E_t \left[\frac{1}{c_{t+1}} \right] E_t [1 + r_{t+1}] + Cov \left(\frac{1}{c_{t+1}}, 1 + r_{t+1} \right) \right).$$

Hence, the covariance between $t+1$ consumption and $t+1$ interest rates determines consumption in period t . In case of positive correlation between said variables, covariance is negative, rendering current consumption more attractive. Additionally, in case of negative correlation between said variables, covariance is positive, rendering current consumption less attractive.

Finally, a tradeoff between current consumption and current leisure can be inferred by equating disutility of additional work with utility of additional consumption, given by

$$\frac{c_t}{1 - l_t} = \frac{w_t}{b}.$$

With high current real wages, current consumption is also high while current leisure is comparably lower.

So, with an external, sector-neutral technology shock hitting the economy, output increases with only slowly dying-off effects. At the same time, both real wages and real interest rates increase, initiating a rise in both, labor supply and consumption on the one hand, and savings on the other. Firms avail of the capital rented out by consumers to invest in new machineries and equipment, for example, increasing capital stock.

By solving the model the following characteristics can be identified:

- As noted above, there is no role for stabilization policy – money supply and government expenditures are expected to exhibit no systematic correlation with real GDP.
- Since the baseline model is a closed-economy case, trade plays no role. Extensions of the baseline model can however capture observed regularities of procyclical and coincidental exports and imports (and countercyclical net exports).
- The real wages and the real interest rate are determined by their marginal products and hence are expected to vary procyclically due to random productivity shocks.
- Employment as determined by the intertemporal substitution decisions of households is expected to vary procyclically since households work more during periods of high productivity of labor and work less during periods of low productivity of labor.
- Investments vary procyclically since households save more during times of high productivity, accumulating capital to be lent out to firms for investments.

- Hence, the capital stock is also expected to vary procyclically due to procyclical investment decisions of firms.
- Consumption is procyclical since marginal utility to consumption is higher in times of higher real wages. Additionally, consumption exhibits lower variability than investments given the consumers' preferences for consumption smoothing.
- Prices are countercyclical due to the shift of the supply function along a negatively sloped demand function.

A closer look at the Austrian business cycles covering the period 1970 to 2004 reveals that all but one prediction of the baseline real business cycle model is met. Real interest rates are expected to vary procyclically, however, the analysis points at a statistically significant negative correlation with real GDP.

Additionally, the two discriminatory factors real wages and prices (CPI) that help to discriminate between the traditional Keynesian demand-side led approach and the RBC supply-side led approach reveal procyclical real wages and countercyclical prices. Hence, the model-free analysis of the basic stylized facts points at the Austrian economy following the real business cycle theory, attributing a leading role to supply-side led factors like technological progress as triggering impulses.

VI. Conclusion/Overall Findings

The Austrian economy underwent two business cycles from the period 1983-2004 broken down into the following—1983-1991 and 1991-2000. The span of the two cycles is eight and nine years, respectively with the third cycle starting in 2000 still ongoing.

The basic characteristics of the cycles are as follows:

1. Volatility, as a preliminary indication of significance for macroeconomic fluctuations, points to investments as the most volatile expenditure component and government expenditures as the least volatile one. This is suggestive of investors' animal spirits affecting economic fluctuations. Additionally, employment and the capital stock appear fairly stable over observed business cycles pointing at significant adjustment costs hampering continuous adjustment of existing capital or labor stocks to economically optimal ones.
2. The co-movements of GDP with all variables, with the exception of government expenditures and money supply, exhibit strong positive correlations while the long-term real interest rates and CPI exhibit strong negative correlations.
3. All key economic variables reveal fairly weak persistence, with total employment, capital stock and CPI as the most persistent and predictable ones.

All but one variable follow the predictions of the baseline real business cycle model (and for exports and imports for an extended model).

The potential source of economic fluctuations for the entire period leads to one dominant culprit – supply-side shocks. This is derived from the significant and negative contemporaneous correlation of prices with output. Additionally, prices seem to significantly lag output by one year pointing at sluggishly adjusting prices. Furthermore, the weak positive, however insignificant correlation of contemporaneous inflation with output supports the finding that fluctuations are more supply-side driven than demand-side driven in origin. Procyclical real wages furthermore point at the significant role of the real business cycle approach for the Austrian economy between 1970 and 2004.

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A. Data Appendix

Table 1A reports standard deviations for different smoothing parameters suggested by the literature and discussed in section I. With little surprise, higher lambdas result in higher standard deviations, hence, more erratic cyclical variations with the most “dramatic” changes observable in time series of real GDP, government expenditures, CPI, capital stock, dependent employment and real wages.

Table 1A Standard Deviation

Variable	Lambda=6.25	Lambda=25	Lambda=100
Real GDP	0.0095	0.0120	0.0154
Government Expenditures	0.0059	0.0082	0.0137
Private Consumption	0.0110	0.0133	0.0171
Investments	0.0411	0.0474	0.0548
Exports	0.0258	0.0317	0.0356
Imports	0.0299	0.0348	0.0404
Money Supply	0.0209	0.0232	0.0252
Real Interest Rate	0.4593	0.5144	0.5434
CPI	0.0092	0.0125	0.0155
Inflation Rate	0.6755	0.7743	0.8518
Capital Stock	0.0034	0.0058	0.0102
Total Employment	0.0047	0.0071	0.0094
Dependent Employment	0.0056	0.0081	0.0121
Real Wage Rate	0.0091	0.0143	0.0219
Labor Productivity	0.0108	0.0121	0.0133

Source: Own calculations

Table 2A describes correlations of all relevant variables with real GDP, determining the variables' cyclicity.

With the exception of the real interest rate and CPI which appear non-significant with a lambda of 100, no variable changes either significance or sign. Hence, at least for the Austrian economy, basic results and inferences are robust to the choice of different smoothing parameters.

Table 2A Correlation with Real GDP

Variable	Lambda=6.25	Lambda=25	Lambda=100
Government Expenditures	0.1762	0.1328	0.3195
Private Consumption	0.6872*	0.7148*	0.7986*
Investments	0.7502*	0.7312*	0.7605*
Exports	0.5135*	0.5988*	0.5758*
Imports	0.6960*	0.7200*	0.7662*
Money Supply	-0.1438	-0.0562	-0.0530
Real Interest Rate	-0.3846*	-0.3602*	-0.2453
CPI	-0.4220*	-0.4129*	-0.1898
Inflation Rate	0.2228	0.2816	0.2416
Capital Stock	0.5028*	0.5793*	0.6809*
Total Employment	0.5793*	0.7094*	0.8016*
Dependent Employment	0.6110*	0.7414*	0.8378*
Real Wage Rate	0.4080*	0.5835*	0.7106*
Labor Productivity	0.8705*	0.7935*	0.7611*

Source: Own calculations

Asterix denotes significant at 5 % level

Results however significantly change once the effect of different smoothing parameters on persistence is analyzed (table 3A). Signs as well as extent of persistence parameters change in almost all cases. With the exception of the real interest rate and the inflation rate, all variables become more persistent with higher lambdas.

Table 3A Persistence

Variable	Lambda=6.25	Lambda=25	Lambda=100
Real GDP	0.0478	0.2741	0.4504
Government Expenditures	0.1128	0.4553	0.7278
Private Consumption	-0.0626	0.1519	0.3781
Investments	-0.0301	0.1474	0.3168
Exports	0.1503	0.3430	0.4358
Imports	0.0443	0.2157	0.3658
Money Supply	-0.1695	0.0177	0.1422
Real Interest Rate	0.4993	-0.0794	0.0121
CPI	-0.0541	0.6215	0.7221
Inflation Rate	0.3898	0.1202	0.2393
Capital Stock	0.4816	0.6785	0.7566
Total Employment	-0.1169	0.6576	0.7268
Dependent Employment	0.4107	0.5896	0.7014
Real Wage Rate	0.5221	0.5738	0.6698
Labor Productivity	-0.1574	-0.0374	0.0628

Source: Own calculations

As to the relevance of supply-side shocks for the Austrian economy captured by correlation coefficients of real GDP with either inflation or CPI, table 4A shows that the correlation of inflation with real GDP is unaffected by the application of different smoothing parameters.

With the exception of the very high lambda of 100, the correlation of real GDP with CPI remains unmodified with different smoothing parameters. Hence, irrespective of the smoothness parameters applied, supply-side shocks seem to be of importance for the Austrian business cycles between 1970 and 2004.

Table 4A Correlation of real GDP with detrended and contemporaneous Inflation or CPI

	Panel A. Filtered Inflation and Output			Panel B. Filtered CPI and Output		
	$\lambda = 6.25$	$\lambda = 25$	$\lambda = 100$	$\lambda = 6.25$	$\lambda = 25$	$\lambda = 100$
Lag	Overall Period	Overall Period	Overall Period	Overall Period	Overall Period	Overall Period
1	0.1959	0.3185	0.2868	0.0941	0.1126	0.2532
0	0.2228	0.2816	0.2416	-0.4220*	-0.4129*	-0.1898
-1	-0.0111	-0.0098	-0.0132	-0.4775*	-0.5588*	-0.4280*

Source: Own calculations

Asterix denotes significant at 5 % level