TIME SERIES PROPERTIES OF THE GERMAN MONTHLY PRODUCTION INDEX

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Abstract

The production index is an important indicator for assessing the cyclical state of the economy. Unfortunately, the monthly time series is contaminated by many noisy components like seasonal variations, calendar and vacation effects. Only part of those nuisance components are explicitly considered in the seasonal adjustment procedures used by statistical agencies.
In this paper, we propose a more flexible specification for the seasonal and working day effects and introduce an indicator for the summer vacations effect. We allow for time-varying parameters and show that the resulting Unobserved Components Model delivers more reliable results for the adjusted series.

JEL Classification: C22, E32.

Keywords: production index, seasonal adjustment, working day effect, business cycles, unobserved components models.

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1 Introduction

Despite the fact that industrial production contributes only about one fourth to German GDP, production indices play still a very important role in assessing the cyclical state of the economy. The main reason may be that in contrast to GDP data production indices are available on a monthly basis and are published with a shorter delay than data for the whole economy. The possible advantages of production indices come with some costs as they are characterised by a high degree of short-run noise due to seasonal fluctuations, the effects of vacations and public holidays as well as other calendar and weather effects. In order to extract a reliable measure of the components of interest, i.e., the trend and the cycle, we need a flexible model which can capture the possibly time-varying effects of the “nuisance”-components.

Most statistical agencies use a variant of the census-method in order to adjust production indices for seasonal and other intra-year fluctuations (for Germany see Jung, 2002, and Kirchner, 1999). Since the census-approach is not explicitly based on a specified time series model (see, e.g., Ladiray/Quenneville, 2000), it is rather difficult to incorporate certain aspects of the production index like month specific variances for random shocks or time-varying effects of the number of different days in a month.

In this study, we use an Unobserved Components (UC) Model for modelling a monthly German production index and decomposing it into the trend, cycle, seasonal, calendar and irregular components. As Harvey/Jaeger (1993) argue, this class of models provides a useful framework as they “are explicitly based on the stochastic properties of the data”. They are based on interpretable and well-defined models for the individual components, are very flexible in accommodating peculiar features of the time series and can be scrutinised by rigorous tests.

The most novel aspect of this study is a more flexible specification of the short-run components than is usually employed in the existing literature. We include an indicator for the effect of summer vacation and for the so called bridging days and allow the parameters to vary over time, the variances of the seasonal shocks to be different for different frequencies (trigonometric seasonal heteroscedasticity in the terminology of Koopman / Franses, 2001) and the variance of the irregular component to be different in different calendar months (seasonal heteroscedasticy).

The organisation of the paper is as follows: In section 2, we present the econometric model and the specification of the unobserved components. Section 3 contains the empirical results for a long time series of the German production index from 1955 to 2001. The final section contains a short summary and some concluding remarks.

2 An Unobserved Components Model for the Production Index

The basic assumption underlying Unobserved Components Models is that an observed time series y_t can be decomposed into several interpretable components (for a general discussion see Harvey 1989; Maravall 1995). In the following, we decompose the logarithm of the monthly production series into the unobserved components trend T, cycle C, season S, the calendar effect A, and the irregular I:

(1) $y_t = T_t + C_t + S_t + A_t + I_t$.

The *trend component* represents the long-run development of production and is specified as a random walk with a possibly time-varying drift rate μ_t:

(2) $T_t = T_{t-1} + \mu_{t-1} + \varepsilon_t$.

The level impulse ε_t is a white noise variable with mean zero and variance σ_ε^2.

The drift rate μ_t is allowed to vary over time and is also defined as a random walk:

(3) $\mu_t = \mu_{t-1} + \xi_t$.

The drift impulse ξ_t is a white noise variable with variance σ_ξ^2.

The model specified in equations (2) and (3) implies that the trend component follows an $IMA(2,1)$-process. Special cases emerge when we set the variance of the shocks to zero. If both are zero, we get a deterministic linear trend. If σ_ξ^2 is zero and σ_ε^2 is strictly positive, the model collapses to a random walk with a constant drift rate. The opposite case with a strictly positive σ_ξ^2 and σ_ε^2 equal to zero gives an integrated random walk with an usually smooth trend component.

The *cycle* C_t captures the fluctuations around the trend component and is modelled as the sum of M subcycles:

(4) $C_t = \sum_{i=1}^{M} C_{t,i}$.

Each subcycle is specified as a vector AR (1) process:

(5) $$\begin{pmatrix} C_{t,i} \\ C^*_{t,i} \end{pmatrix} = \rho_i \begin{pmatrix} \cos \lambda_i^C & \sin \lambda_i^C \\ -\sin \lambda_i^C & \cos \lambda_i^C \end{pmatrix} \begin{pmatrix} C_{t-1,i} \\ C^*_{t-1,i} \end{pmatrix} + \begin{pmatrix} \kappa_{t,i} \\ \kappa^*_{t,i} \end{pmatrix}.$$

C^* appears only by construction and has no intrinsic interpretation.

The period of subcycle i is $2\pi/\lambda_i^C$. The damping factor ρ_i with $0 < \rho_i \le 1$ ensures that $C_{t,i}$ is a stationary $ARMA(2,1)$ process with complex roots in the AR-part (see Harvey, 1989). This guarantees a quasi-cyclical behaviour of $C_{t,i}$. The shocks $\kappa_{t,i}$ and $\kappa^*_{t,i}$ are assumed to be uncorrelated white noise variables with common variance $\sigma^2_{\kappa_i}$. They induce a stochastically varying phase and amplitude of the wave-like process. The total cycle C_t is an $ARMA(2M, 2M-1)$ process with restricted MA-parameters.

The *seasonal component* captures the typical intra-year fluctuations of production. For example, in most years we observe a trough in production in August and a peak in November. The seasonal fluctuations in production are caused by seasonal fluctuations in demand, by weather effects on productivity and by the division of vacation times over the different months. As will be explained below, parts of these effects are modelled as functions of observable variables.

The seasonal effect is specified as the sum of six cycles with the seasonal frequencies $\lambda_i = 2\pi\, i/12$, i = 1, 2,..., 6:

(6) $S_t = \sum_i S_{t,i}$.

Following Harvey (1989), we specify each seasonal cycle by a stochastic recursive formula:

(7) $$\begin{pmatrix} S_{t,i} \\ S^*_{t,i} \end{pmatrix} = \begin{pmatrix} \cos \lambda_i & \sin \lambda_i \\ -\sin \lambda_i & \cos \lambda_i \end{pmatrix} \begin{pmatrix} S_{t-1,i} \\ S^*_{t-1,i} \end{pmatrix} + \begin{pmatrix} \omega_{t,i} \\ \omega^*_{t,i} \end{pmatrix}.$$

In an analogous way to the specification of the cycle component, the auxiliary variable S^* is only used for building up the recursion.

The seasonal shocks $(\omega_{t,i}, \omega^*_{t,i})$ are two uncorrelated white noise random variables with common variance $\sigma^2_{\omega_i}$. If the variance of a seasonal shock is greater than zero, the seasonal pattern changes over time. In most applications, the variances of the seasonal shocks are restricted to be constant over the different seasonal frequencies. In order to get a more flexibel model, we allow for different variances for different frequencies (this feature is called trigonometric seasonal heteroscedasticity by Koopman/Franses, 2001).

The *calendar effect* A_t comprises the working day effect D_t, the bridging day effect B_t and the main vacation effect V_t. The *working day effect* D_t is caused by the varying number of the different days of the week and the occurence of public holidays. In exploratory work we tried different specification for the working day effect (see for example, the suggestions in Harvey, 1989, and Ladiray/Quenneville, 2001). The best model (evaluated by the diagnostic measures presented below) is given by

(8) $$D_t = \sum_j \beta^{(1)}_{t,j} \left(TD_{t,j} - \overline{TD_j}\right),$$

where $TD_{t,j}$ denotes the number of days of type j in period t and $\overline{TD_j}$ is the average number of days of type j over the estimation period. The weighting parameters β are allowed to change over time (see below). This formulation ensures that the working day effect has approximately a zero average over the estimation period. The precise definition of the different types of days is given below in the empirical section.

If a public holiday falls on a Tuesday or a Thursday, many workers choose to take a vacation day at Monday or Friday, respectively. Those days are called “Brückentage” (bridging days). In months with more bridging days, production is expected to be lower. The bridging day effect is specified as

(9) $$B_t = \beta^{(2)}_t \left(TB_t - \overline{TB}\right),$$

when TB_t is the number of bridging days in month t, and $\overline{TB}$ is the average number of bridging days over the estimation period.

In Germany, the main vacation period starts mid June and ends early September. Unfortunately, we have no statistic on the distribution of the vacation of produc tion workers over these months. Instead, we use the pattern of school holidays as an indicator variable. The vacation effect is specified as

(10) $V_t = \beta_t^{(3)} \quad (VS_t - 0.25)$,

where VS_t is the proportion of summer school holidays in a given year which falls in period t (for a detailed description of VS see the appendix). Note that VS_t is zero for all months with the exception of June, July, August and September. $(VS_t - 0.25)$ measures the deviation of the actual distribution from a hypothetical uniform distribution of the vacation period over the four vacation months. The specification (10) ensures that the vacation effect is approximately zero over a year.

We expect that the parameters β in equations (8) to (10) are not constant over time. For instance, the number of working hours per week shows a sharp decrease from about 45 hours in the late fifties to about 37 hours at the end of the nineties, the number of vacation days increased from 15 to more than 30 and the phenomenon of flexitime is now much more common than it used to be in the past. For all these reasons, we suspect that the importance of the number of working and bridging days as well as the vacation period is changing over time.

In order to allow for possibly time-varying effects, we specify the parameters $\beta_t^{(i)}$, $i = 1, 2, 3$ as random walks

(11) $\beta_t^{(i)} \quad = \quad \beta_{t-1}^{(i)} + \eta_{\ t,i}$,

where $\eta_{t,i}$ is a white noise random shock with variance $\sigma_{\eta_i}^2$.

The *irregular component* comprises a deterministic and a stochastic component:

(12) $I_t = \gamma_0 \ DI_t + u_t$.

DI_t is a dummy variable which takes the value 1 in a certain period and the value 0 in all other periods. The deterministic component $\gamma_0 \ DI_t$ (the impulse intervention) captures outliers which reflect identifiable events and u_t reflects temporary shocks which are modelled as a stochastic variable. In most applications, u_t is assumed to be a white noise variable with a constant variance σ_u^2.

A careful look at the estimated irregular component and the one-step prediction error shows that this assumption is greatly at odds with the empirical facts: The standard errors are in some months (especially in July, August and December) much higher than in other months (e.g., in October or November). For this reason we allow the variance of the random component of the irregular to follow a deterministic seasonal pattern:

(13) $Var\left(u_t\right) = \sigma_u^2\left(\tau\right), \tau = 1,\ldots,12$,

where τ denotes the month (January, . . . , December) in which period t falls. This feature of month-specific variances of the irregular component is called seasonal heteroscedasticity by Koopmann/Franses (2001). For alternative specifications of seasonal heteroscedasticity see Jaditz (2000), Campbell/Diebold (2001) or Burridge/Wallis (1990).

It is assumed that all disturbances are normally distributed and are independent of each other. This is the usual assumption to assure the identification of the parameters (see, e.g., Watson 1986).

Estimation of the model parameters is carried out by maximum likelihood in the time domain. The initial values for the stationary cycle components are given by the unconditional distribution and for the nonstationary trend, drift and seasonal components by a diffuse prior. The time-varying parameters β in equations (8) to (10) are also initialised by using a diffuse prior. The filtered and smoothed values of the unobserved components are generated by the Kalman filter (for details see Harvey 1989).

3 Empirical results

The variable analysed in this study is a monthly index of German industrial production, defined as the output of manufacturing, mining and energy producing utilities (for details see Appendix). The estimation period includes 564 months, extending from January 1955 to December 2001.

In a first step, we seek for a parsimonious specification of the working day effect and for possible outliers which should be controlled for by a deterministic intervention variable. In all versions it turns out that the estimated values for the smoothed irregular component were exceptionally high in December 1967 (positive) and July 1984 (negative). The December 1967 outlier may be due to a fundamental change in the tax system in January 1968 (introduction of the value added tax) which led to a temporarily increase in production in the previous month. The outlier in July 1984 can be easily explained by a strike in the metal industry.

Concerning the working day effect, an intensive search over several specifications was carried out. In the basic model, the number of Mondays, Tuesdays, ..., Saturdays, that are not public holidays, the number of Sundays and the number of public holidays were included as explanatory variables. It turns out that the estimated time-varying parameters for the number of Mondays to Fridays (that are not holidays) are not significantly different from each other and that the parameters for the number of Sundays and the number of holidays are likewise almost identical. Consequently, in the final model, we use the sum of the number of Mondays to Fridays (that are not holidays), the number of Saturdays (that are not holidays) and the sum of the number of Sundays and holidays as the three variables for modelling the working day effect. This specification is more flexibel than the approach used by the German statistical office and the Bundesbank where Saturdays have the same effect as Sundays and holidays (see Kirchner, 1999). The "Bundesbank-restriction" was clearly rejected in all models we present below.

Given the specification for deterministically modelled outliers and for the working day effect, we estimate eight different models which differ with respect to the form of seasonal heteroscedasticity, the inclusion of bridging days and the vacation indicator.

Model I, called the extended basic structural time series model, consists of a stochastic trend, cycle and seasonal component, but includes none of the working day, bridging day and vacation effects and assumes a constant variance for the seasonal shocks of different frequencies as well as a constant variance of the irregular over the months of a year.

Model II adds the working day effect, model III in addition the bridging day effect and model IV the main vacation effect. Model V allows for trigonometric seasonal heteroscedasticity and model VI in addition for seasonal heteroscedasticity of the irregular component. As explained in detail below, model VIa imposes some restrictions on the monthly variances of the irregular. Model VII is equal to model VIa with the exception that the cyclical component is specified as the sum of two subcycles (for some evidence concerning German GDP, see Flaig, 2002). Table I gives a short summary of the estimated models.

Table I: Summary of Estimated Models

Model I	Extended basic structural time series model
Model II	Model I + working day effect
Model III	Model II + bridging day effect

Model IV	Model III + main vacation effect
Model V	Model IV with trigonometric seasonal heteroscedasticity
Model VI	Model V with seasonal heteroscedasticity for irregular
Model VI a	Model VI with restrictions for variances of irregular (see text)
Model VII	Model VI a with two cycles

We compare the quality of the different models by using several fit criteria and diagnostic measures. Since we initialise the non-stationary elements of the state vector by a diffuse prior, the likelihood function is effectively calculated by using the one-step-ahead prediction errors for the periods $d+1, ..., T$, where d denotes the number of non-stationary states and T is the number of observations (to be concrete, we maximise the likelihood function as given by equation (4.2.3) in Harvey, 1989; for an exact solution see Durbin/Koopman, 2001) . In order to be able to compare the fit criteria for models with a different number of non-stationary state variables, we normalise the likelihood function $\ln L$ by multiplying it by the factor $T/(T-d)$. The expression $\ln L^* = \ln L \cdot (T/T-d)$ specifies the value of the likelihood function per effective observation multiplied by the total number of observations. Due to well-known problems with the application of likelihood-ratio tests for structural time series models (see Harvey, 1989), we use $\ln L^*$ only in an informal way and rely on the Akaike and Schwarz information criteria. Further, we check the standardised prediction errors for the presence of autocorrelation and non-normality by using the Box-Ljung and Jarque-Bera test, respectively.

The results are presented in Table 2. As it turned out that the variance of the level shock ε_t (equation (2)) has in all models an estimated value of zero or almost zero, we impose this restriction for all versions presented in the following. All criteria show very clearly that the inclusion of the working day and the bridging day effect as well as the main vacation indicator improves considerably the quality of the model (compare models II to IV with the basic model I). Whereas the working day effected is taken into account by procedures used in official statistical agencies, the latter two effects are mostly neglected. Model V reveals that the assumption of a common variance for the seasonal shocks of different frequencies (equation (7)) is to restrictive and should be relaxed. In model VI, we allow for month-specific variances of the irregular component. The evidence is somewhat mixed. Whereas the Akaike information criterion indicates an improvement, the Schwarz information criterion shows a deterioration. The latter is due to the fact that the Schwarz criterion penalises the additional eleven parameters very heavily. A closer look at the estimated variances reveals that the estimated variances are very similar in January and March, in July and in December, and in the group of the other months, respectively.

If we impose the according restrictions, both the Akaike and the Schwarz information criterion select model VIa with seasonal heteroscedasticity of the irregular shock as the best. Finally, in model VII we specify the cyclical component as the sum of two subcycles. Despite the fact that the Schwarz criterion deteriorates, we choose version VII as our preferred model. Model VII delivers the best result concerning the Akaike criterion (for some arguments why AIC is a reliable measure for model selection see Kitagawa/Gersch, 1996) and shows no sign of misspecification.

Table 2: Summary Statistics

Model	$\ln L^*$	AIC	SIC	LB	JB	σ_{RR}
I	1,037.3	-2,032.6	-1,942.0	278.6	0.6	0.0385
II	1,494.9	-2,933.7	-2,813.1	13.7	5.9	0.0172
III	1,503.0	-2,948.0	-2,823.2	11.8	9.4	0.0170
IV	1,556.7	-3,051.3	-2,917.9	18.3	4.3	0.0167
V	1,576.9	-3,081.9	-2,927.0	5.4	4.5	0.0163
VI	1,592.1	-3,090.2	-2,887.9	5.9	1.2	0.0162
VI a	1,589.7	-3,102.9	-2,939.4	5.8	1.2	0.0161
VII	1,595.6	-3,109.2	-2,932.8	4.3	1.2	0.0159

Note: $\ln L^*$ is the normalised value of the maximised likelihood function, AIC the Akaike information criterion, SIC the Schwarz information criterion, LB the Ljung-Box-statistic with 12 lags, JB is the Jarque-Bera test-statistic, and σ_{RR} is the standard deviation of the one-step prediction errors.

Table 3 presents the estimated parameters for model VII. Almost all of the estimated standard deviations of the various shocks are highly significant and imply that the unobserved components (trend, cycles, etc.) are stochastically varying over time. The effects of the individual parameters are explained in detail below.

Table 3: Parameter Estimates for Model VII

Trend	σ_ξ: 1.64 (2.9)		
Season	σ_{ω_1}: 10.53 (6.3) σ_{ω_4}: 0.0 (0.0)	σ_{ω_2}: 4.92 (3.8) σ_{ω_5}: 1.99 (2.8)	σ_{ω_3}: 4.43 (4.2) σ_{ω_6}: 1.01 (1.4)
Cycle	ρ_1: 0.977 (206.4) ρ_2: 0.993 (885.1)	λ_1^C: 0.118 (13.3) λ_2^C: 0.054 (8.6)	σ_{κ_1}: 57.44 (13.2) σ_{κ_2}: 36.80 (9.3)
Working Day Effect	$\sigma_{\eta_1}^{(1)}$: 2.99 (2.8)	$\sigma_{\eta_2}^{(1)}$: 2.70 (1.9)	$\sigma_{\eta_3}^{(1)}$: 0.0 (0.0)
Bridging Day Effect	$\sigma_\eta^{(2)}$: 4.33 (2.3)		
Vacation Effect	$\sigma_\eta^{(3)}$: 50.82 (10.3)		
Irregular	$\gamma_{67:12}$: 0.066 (5.9) $\sigma_u^{(1)}$: 70.84 (16.2)	$\gamma_{84:6}$: -0.132 (12.3) $\sigma_u^{(2)}$: 109.68 (13.0)	$\sigma_u^{(3)}$: 41.84 (23.1)

Note: All standard deviations of shocks have to be multiplied by 10^{-4}. Numbers in parentheses denote t-values.

The three values for the standard deviations of the working day effect refer to the parameter of the number of Mondays to Fridays, Saturdays, and Sundays and holidays, respectively. The three values for the standard deviations of the irregular component refer to January and March, July and December, and to the other months, respectively.

In the following, we discuss the evolution of the unobserved components as well as the time-varying model parameters for the working day, the bridging day and the vacation effects. The figures display the smoothed values which were generated by the fixed-interval smoother.

Figure 1 shows the logarithm of the production index (thin line) and the estimated trend component (thick line). The graph demonstrates how flexible a specification with a time-varying drift rate can accommodate the slowdown of the growth rate in the early sixties and early seventies as well as the hump in the second half of the eighties.

Figure 1: Production Index (thin line) and Trend Component (thick line)

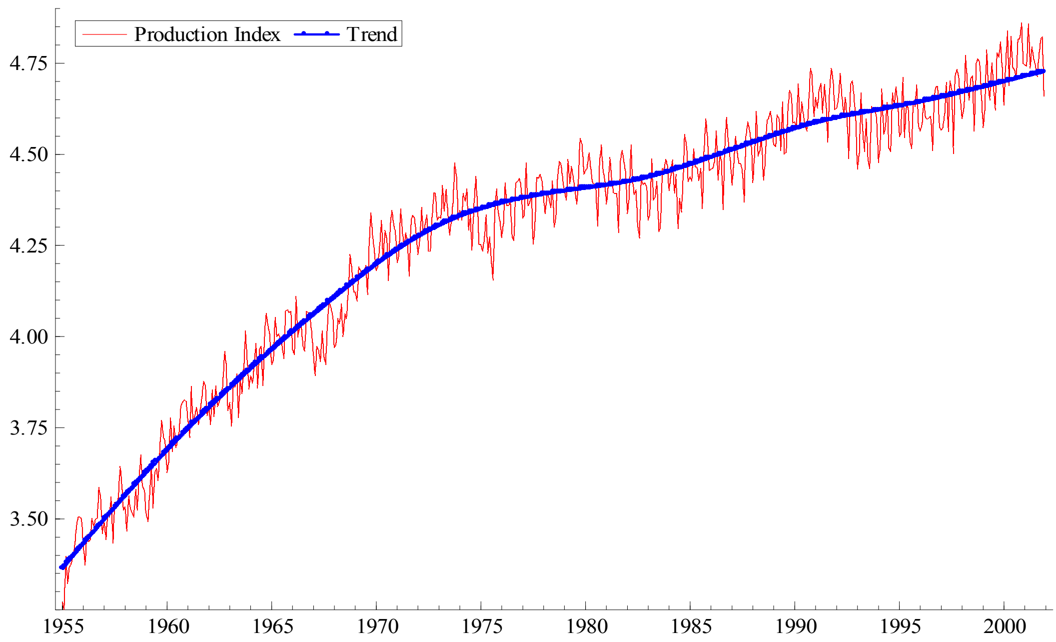


Figure 2 displays the short- and the long cycle as well as the total cycle. The short cycle has a period of 53 months (4.4 years) and a standard deviation of 0.023, the long cycle has a period of 116 months (9.7 years) and a standard deviation of 0.026. The total cycle has a standard deviation of 0.038.

It is interesting that in previous work (Flaig 2002) we found a similar cyclical pattern for quarterly German GDP in the period from 1960 to 2001. The estimated periods for the two subcycles of GDP are 4.1 and 8.1 years. Whereas the periodicity of the short cycle is almost identical for GDP and the production index, the periodicity of the long cycle of GDP is 1.6 years higher than in case of the production index. But since the standard error for the periodicity of the long cycle is 1.2 years, we can conjecture that GDP and industrial production follow similar cycles. A formal investigation of this conjecture is left for future research.

Figure 2: Short Cycle, Long Cycle and Total Cycle

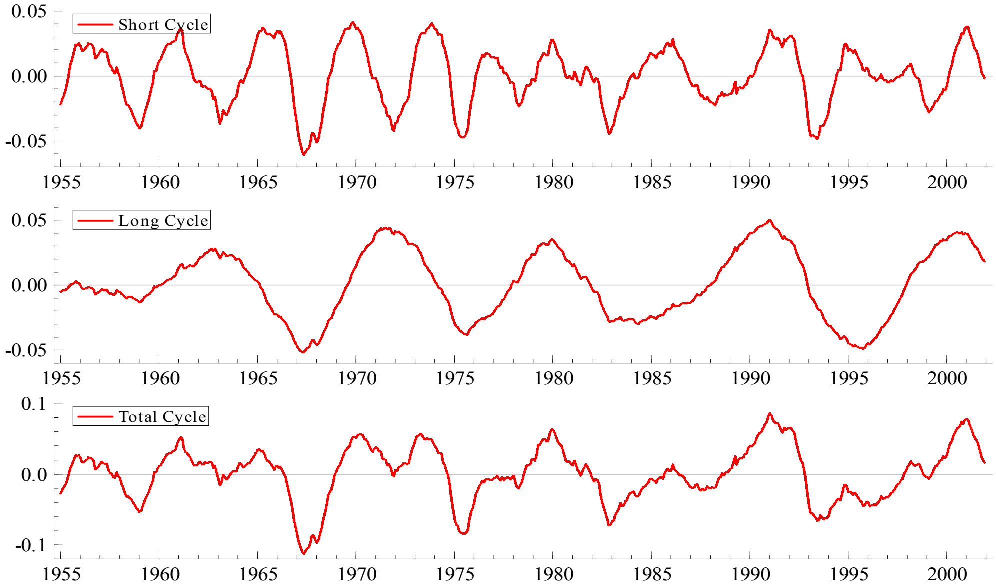


Figure 3 displays the smoothed estimate of the seasonal component. As can easily be seen, the seasonal pattern is changing over time. Especially the yearly minima (in January, July and August) are much more pronounced in the second half of the sample than in the fifties and sixties. In the last 15 years, we observe a slight reduction in the seasonal fluctuations. The variable seasonal pattern casts some doubts on the claim of some authors (see, e.g., Miron, 1996) that the seasonal cycle could reasonably be modelled by using fixed seasonal dummies.

Imposing the restriction that the variances of the seasonal shocks are zero (which is equivalent to assuming a fixed seasonal pattern) leads to high autocorrelation of the recursive residuals and is rejected by all diagnostics. A stochastic seasonal process is essential for an adequate specification. It is a very misleading assertion that “these processes allow for Christmas to migrate to July” (Miron, 1996, p.8). But they allow, e.g., that the strength of Christmas effect is changing over time. And that is what we would expect to occur over longer time horizons.

Figure 3: Season

Figure 4 and Figure 5 display the estimated parameters for the calendar effects. The topmost curve in Figure 4 shows the time-varying parameter for the number of Mondays to Fridays. The parameter starts in 1955 with a value of 0.034, increases to 0.037 in 1961, falls then to a minimum of 0.032 in the seventies and shows since then an increase to about 0.038. The next curve from the top refers to the Saturday effect. The parameter decreases steadily from 0.019 to 0.012 in the eighties and increases since then slightly to a value of about 0.014. The sharp decrease is due to the fact that Saturday was abolished as a regular working day during the fifties and sixties, the increase during the last two decades reflects the attempt of firms to use their plant also on Saturdays.

The thick horizontal line with a value of 0.058 represents the Sunday and holiday effect on production. Since the variance of the shock for this parameter is zero, the smoothed parameter is constant over the last fifty years. The curve in the bottom part of Figure 3 shows the parameter for the bridging day effect. It is relatively small until the middle of the seventies but then triples (in absolute terms) in the last two decades. The higher importance of bridging days since the seventies is mainly caused by the already mentioned high increase in the total number of vacation days which are used to take a day off before or after a public holiday.

Figure 4: Estimates for the Parameters of the Working Day and Bridging Day Effects

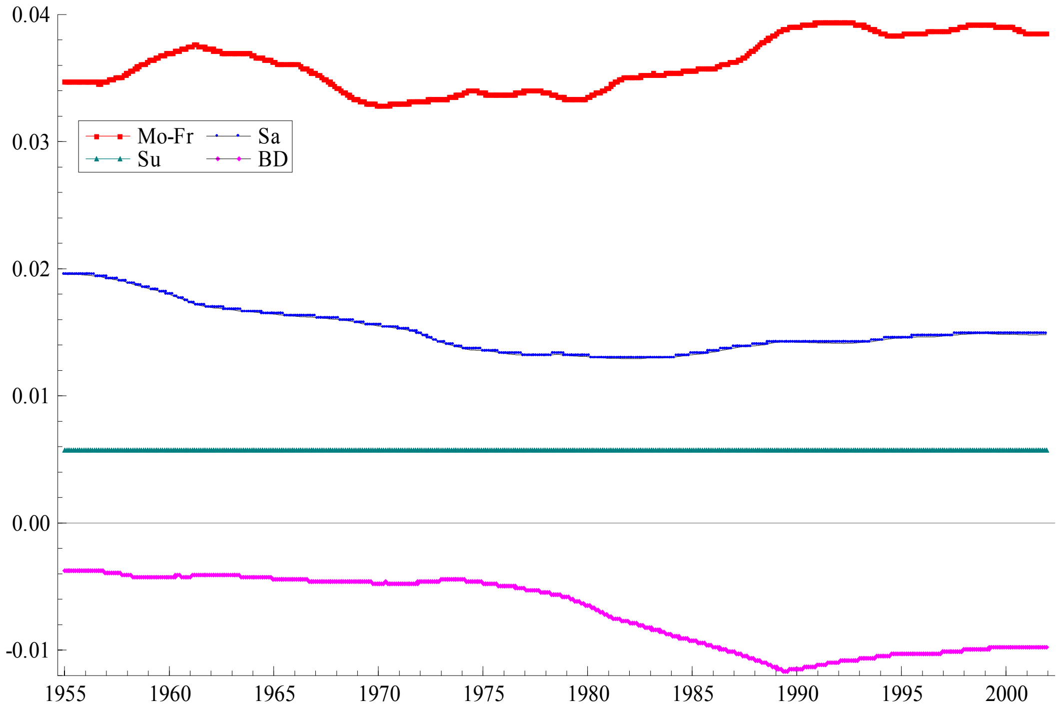
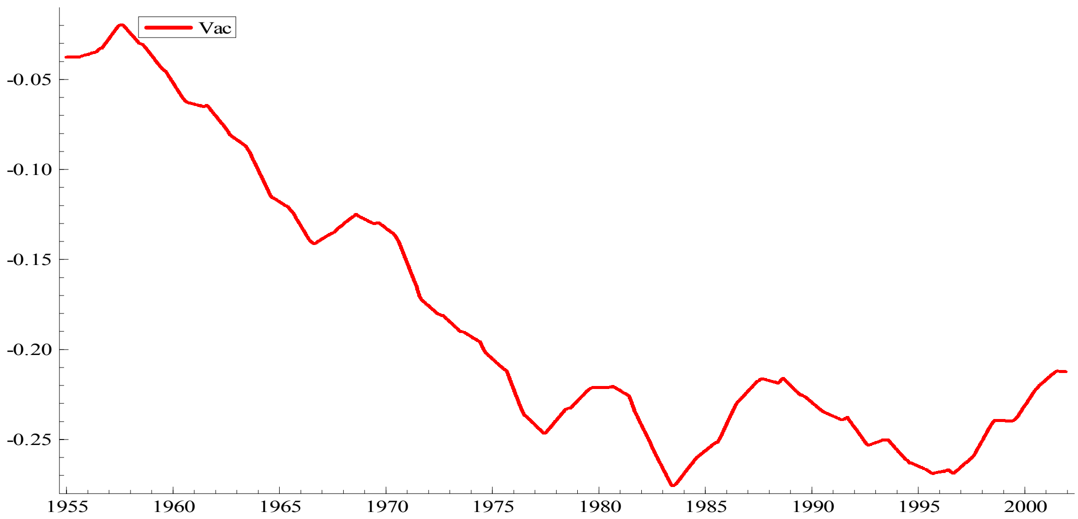


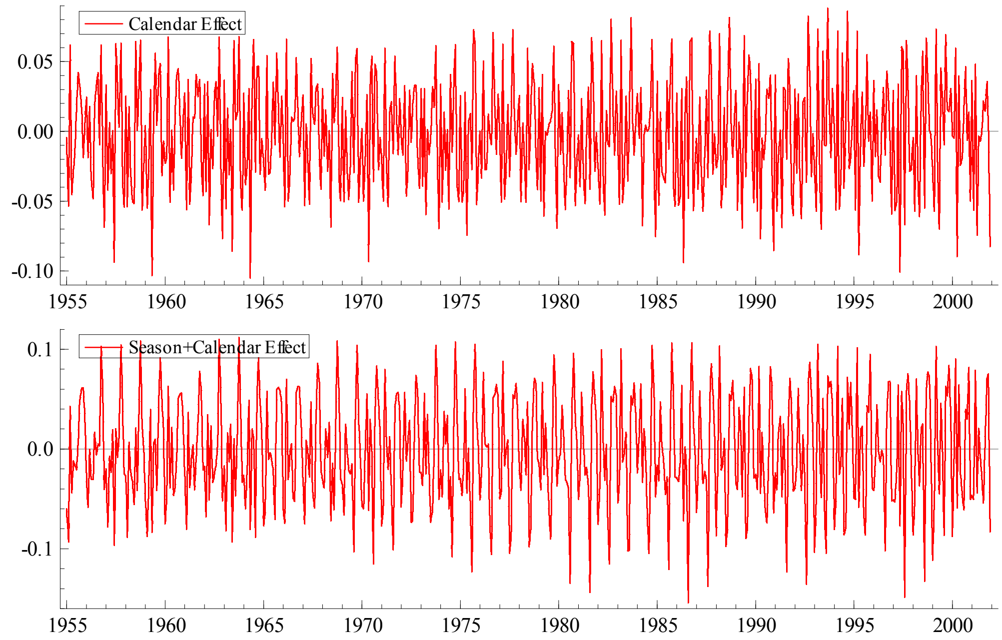
Figure 5 presents the smoothed values for the parameter of the summer vacation effect. In a qualitative sense, the parameter exhibits similar properties as the parameter for the bridging day effect. The parameter shows a pronounced trend until the mid seventies and fluctuates since then around the value -0.25.

Figure 5: Estimates for the parameter of the Vacation Effect



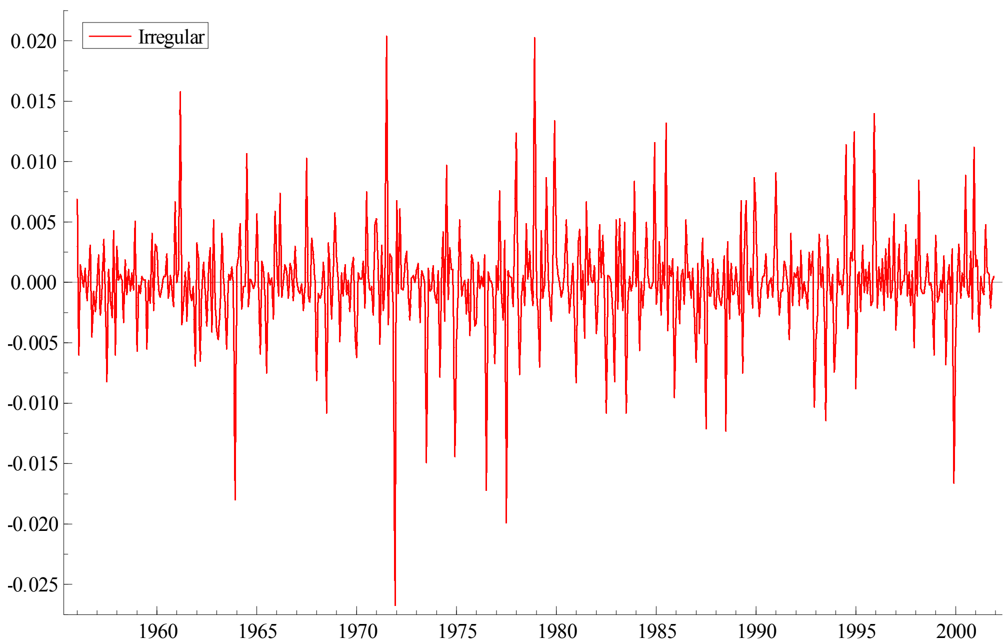
The total calendar effect comprises the working day, the bridging day and the summer vacation effect. It's contribution to the short-run dynamics of production is shown in the top part of Figure 6. As the decomposition of the intra-year fluctuations into the seasonal and calendar component is somewhat arbitrary, the sum of both components is displayed in the bottom part of Figure 6. When we compare Figure 6 with Figure 2, we see that the intra-year fluctuations are almost one and a half as large as the fluctuation at business cycle frequencies. There is an enormous short-run volatility of production which have to be modelled very carefully in order to purge the time series from noisy elements.

Figure 6: Total Calendar Effect



The smoothed values for the irregular component are presented in Figure 7. As could be expected from the estimated values for the month-specific variances of the irregular (see Table 3), the highest values occur in January and March and especially in August and December.

Figure 7: Irregular Component



4 Summary and Conclusions

In this study, we use an Unobserved Components Model for decomposing the monthly German production index into trend, cycle, season, the calendar effects and the irregular. The most important results can be summarised as follows:

1. The trend component can successfully be modelled as an integrated random walk, i.e., as an I(2)-process. This specification is able to reproduce the slow-down in the long-run growth rate during the early sixties and early seventies. A specification of the trend component as an I(1)-variable with a constant drift rate would not be able to capture this pattern.
2. The cycle consists of two subcycles with a period of 4.4 and 9.7 years, respectively. This is in full accordance with empirical results for German GDP (see Flaig 2002) and central ideas in classical business cycle theory about Kitchin- and Juglar-cycles.
3. The seasonal pattern of production is changing over time. A stochastic specification of the seasonal component is a crucial feature of a satisfactory time series model for the production index. In addition, we observe trigonometric heteroscedasticity. The variances of the seasonal shocks are different for the different seasonal frequencies. The restriction of a constant variance as for instance imposed in STAMP (Koopman / Harvey / Doornik / Shephard, 2000) seems not to be the best choice at least for the time series analysed in this paper.
4. For a successful modelling of the working day effect it seems to be necessary to distinguish between four types of days: Weekdays, Saturdays, Sundays and public holidays, and bridging days. As yet, the bridging day effect is not taken into account by any official seasonal adjustment procedure. The same is true for the summer vacation effect which is caused by the time-varying start and end of school holidays. In addition, the parameters for these variables are changing over time. A constant parameter as imposed in all seasonal adjustment procedures is to restrictive, especially if we analyse long time series. The results of this paper delivers strong evidence that the "official" seasonal adjustment procedures can considerably be improved by taking into account the bridging day and vacation effect. This observation may be relevant also in other countries in which these phenomena are important.
5. The variability of the irregular component is not constant over the months of a year. The variance is especially high in January, March, July and December. January, July and December may sometimes be affected by very cold or hot

weather conditions but the main cause is probably a vacation effect around Christmas and Easter as well as a peculiar effect in July which is not fully captured by the school holiday indicator developed in this paper.

As yet we have not found a satisfactory specification of the Easter and Christmas effect as a function of observable variables (for a discussion of different approaches see Ladiray/Quenneville, 2001). It is left for future work to carry out a systematic specification search in order to reduce the variance of the irregular component.

6. Unobserved Components Models are a very useful and efficient approach for modelling economic time series with complex properties like stochastic trend and seasonal components, time-varying parameters of explanatory variables and period-specific variances of shocks. They are far more flexible than ARIMA-models commonly used in empirical work.

Appendix: Data

The production index comprises total industry, excluding construction. The data for 1955 to 1990 refer to West Germany and are taken from the CD-ROM “50 Jahre Deutsche Mark”, published by Deutsche Bundesbank. The data for 1991 to 2001 cover Germany and are taken from the CD-ROM “STATIS”, published by Statistisches Bundesamt. The index values from 1955 to 1990 are multiplied by the factor 1,054 in order to take account for a change in the base year.

The number of working days, bridging days, and public holidays are calculated by a GAUSS program, written by the author (available on request). We count for every months in the sample how often each day of the week occurs and how many public holidays fall on each day of the week. We take into account that some of the public holidays are valid only in part of the German Länder. Public holidays are: January 1st, January 6th (Epiphany, 0.3), Good Friday, Easter Monday, May 1st, Ascension, Corpus Christi Day (0.7), Whit-Monday, June 17th (until 1990), August 15th (Assumption Day, 0.2), October 3rd (German Unification Day, since 1990), Reformation Day (0.1, since 1991), All Saints’ Day (0.6), Christmas Eve (0.5), New Years’ Eve (0.5).

When a public holiday falls on a Tuesday or on a Thursday, many people take a vacation at the preceding Monday or the following Friday, respectively. These days are called bridging days (Brückentage). Each bridging day is counted with the weight of the corresponding public holiday.

In contrast to other countries, in Germany the summer vacation period of workers is not fixed but is mainly determined by school holidays which change from year to year in each federal state. The secretariat of the Deutsche Kultusministerkonferenz provided kindly the dates of the school holidays in every federal state since 1955. From this information we calculated for each state the proportion of school holiday which fall in June, July, August and September, respectively. The figure for the whole country was calculated as a weighted average where the weight of a state is given by its share of the number of production workers.

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