Appendix to "The Effects of Institutional and Technological Change and Business Cycle Fluctuations on Seasonal Patterns in Quarterly Industrial Production Series"

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This appendix contains additional empirical results, not included in the main text in order to save space.

Seasonal patterns in Canada, France, Italy and the US

Figure A.1 shows graphs of the first difference per quarter, and the seasonal difference of the log industrial production series for Canada, France, Italy and the US. The differenced and seasonally differenced series are multiplied by 100 to express the changes in percentage points.

A common feature for Canada and France, shared by Germany and the UK, is that the seasonal variation in the industrial output series appears to have dampened over time. In particular, the drop in output in the third quarter and the fourth-quarter peak have become less pronounced. This is not true, however, for Italy, where rather the opposite has occurred. The US series does not show a third-quarter summer holiday decrease. In the US, the quarterly growth in the 1990s is actually highest in the third quarter and lowest in the fourth quarter.

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Testing for changes in seasonal patterns in STAR models

As discussed in the main text, an objection that can be raised against the tests for nonlinearity and structural change in the seasonal patterns of the industrial production series as presented Table 1 of the main text is that the test results (in cells (Δy_{t-j}, STAR)) also suggest that the dynamic behaviour of some of the industrial production series may be nonlinear. For some other series a case can be made for a TV-AR process, that is, the dynamic behaviour may be time-varying because of phenomena proxied by time. It may therefore be argued that the results just presented are affected by misspecification of the null model and that in order to avoid this, it should already accommodate non-seasonal nonlinearity.

In order to consider this possibility we proceed as follows. Consider the row of linearity tests (Δy_{t-j}) in Table 1. We choose the type of transition variable, either a lag of $\Delta_4 y_t$ or t^*, for each series by comparing the p-values of the tests against STAR and against TV-AR. If the p-value of the test against STAR is smaller than the one for TV-AR, we choose a STAR model, otherwise we proceed with a TV-AR model. In this case, both LM_k statistics yield the same result for France, Japan, the UK (TV-AR), Germany and the US (STAR). For Canada and Italy, we obtain conflicting results but, considering the two statistics jointly, it appears that the evidence for STAR is somewhat stronger than the evidence for TV-AR for Canada, while the reverse holds for Italy. Next, we specify and estimate a STAR or TV-AR model for Δy_t, with the seasonal dummies only entering linearly, following the modelling strategy described in, for example, Teräsvirta (1998) and van Dijk, Teräsvirta and Franses (2002). We then test the constancy of the coefficients of the seasonal dummy variables within this model, as shown in (7). The p-values of the appropriate test statistics can be found in Table A.1, where the first column of the table gives the transition variable used in the null model.

It is seen that the basic message is still the same, although the p-values are somewhat higher than before. Obviously, some of the seasonal variation has been absorbed by the re-specified dynamic structure of the model. Nevertheless it seems that the seasonal parameters are still changing over time for unspecified reasons rather than as a function of the cyclical fluctuations in the economy. At the 5% level, $\mathsf{H}_0^{\text{STAR},D_{s,t}}$ can only be rejected for one of the tests for Japan and the UK. Rejections against TV-AR are still the rule, in particular when the LM_3 test is considered. Allowing for time-varying or nonlinear autoregressive dynamics eliminates the evidence for “Kuznets-type” change in the seasonal pattern only for the UK and the US. In those cases, the null model thus influences our view of the situation.

TV-STAR models for Canada, France, Italy and the US

All models reported below are estimated over the sample period 1963:2-2001:3 (154 observations), except for Canada for which the estimation period is 1964:2-2001:3. Misspecification tests are given in Table A.2. Figures A.2-A.5 depict the value of the deterministic seasonal component and the transition functions in the TV-STAR models.

Canada

In the seasonality-augmented linear AR model for Canada, linearity of the seasonal dummy coefficients is rejected most strongly against "Kuznets"-type unspecified change; see Table 1 in the main text. However, a TV-AR model with the standard logistic transition function (1) does not satisfactorily describe the variation in the seasonal pattern. This is not surprising given the way the seasonal pattern evolves, as shown in Figure A.1. A TV-AR model with a generalized logistic function (6) with $k = 2$ also is inadequate, because the decline in the amplitude of seasonal fluctuations after 1978 is different (both in terms of magnitude and speed) from the increase during the first part of the sample, as shown in Figure A.1. We therefore use an additive TV-AR model with two standard logistic functions. After sequentially deleting insignificant coefficients and increasing the maximum lag order to 11 to capture remaining autocorrelation in the residuals, we obtain the model

$$\begin{aligned}\Delta y_t = &\underset{(0.38)}{1.50} - \underset{(0.58)}{1.44}\, D^*_{1,t} - \underset{(0.79)}{1.44}\, D^*_{3,t} + \underset{(0.076)}{0.29}\, \Delta y_{t-1} \\ &+ \underset{(0.070)}{0.37}\, \Delta y_{t-2} - \underset{(0.086)}{0.15}\, \Delta y_{t-3} - \underset{(0.076)}{0.24}\, \Delta y_{t-5} - \underset{(0.066)}{0.18}\, \Delta y_{t-11} \\ &+ (-\underset{(0.40)}{1.01} + \underset{(1.21)}{5.59}\, D^*_{1,t} - \underset{(1.14)}{7.37}\, D^*_{2,t} - \underset{(1.34)}{3.83}\, D^*_{3,t}) \times G_1(t^*;\gamma_1,c_1) \\ &+ (-\underset{(0.74)}{1.40}\, D^*_{1,t} + \underset{(0.71)}{3.43}\, D^*_{2,t} + \underset{(0.70)}{1.48}\, D^*_{3,t}) \times G_2(t^*;\gamma_2,c_2) + \widehat{\varepsilon}_t, \end{aligned} \tag{A.1}$$

$$G_1(t^*;\gamma_1,c_1) = (1+\exp\{-\underset{(0.79)}{3.38}\,(t^* - \underset{(0.024)}{0.24})/\sigma_{t^*}\})^{-1}, \tag{A.2}$$

$$G_2(t^*;\gamma_2,c_2) = (1+\exp\{-\underset{(30.2)}{30.2}\,(t^* - \underset{(0.011)}{0.68})/\sigma_{t^*}\})^{-1}, \tag{A.3}$$

$\widehat{\sigma}_\varepsilon = 1.38$, $\widehat{\sigma}_{\text{TV-STAR/AR}} = 0.84$, SK $= -0.33(0.051)$, EK $= 0.43(0.14)$, JB $= 3.84(0.14)$, $\text{LM}_{\text{SC}}(1) = 0.14(0.71)$, $\text{LM}_{\text{SC}}(4) = 1.00(0.41)$, $\text{LM}_{\text{SC}}(12) = 0.86(0.58)$, ARCH(1) $=$ $0.86(0.35)$, ARCH(4) $= 5.28(0.26)$, $\text{AIC}_{\text{TV-STAR/AR}} = -0.25$, $\text{BIC}_{\text{TV-STAR/AR}} = -0.085$,

where OLS standard errors are given in parentheses below the parameter estimates, $\widehat{\varepsilon}_t$ denotes the regression residual at time t, $\widehat{\sigma}_\varepsilon$ is the residual standard deviation, $\widehat{\sigma}_{\text{TV-STAR/AR}}$ is the ratio of the residual standard deviations in the estimated TV-STAR model (A.1) and the best fitting subset AR model, SK is skewness, EK excess kurtosis, JB the Jarque-Bera test of normality of the residuals, $\text{LM}_{\text{SC}}(j)$ is the LM test for no residual autocorrelation up to and including lag j, ARCH(q) is the LM test of no ARCH effects up to order q, and $\text{AIC}_{\text{TV-STAR/AR}}$ and $\text{BIC}_{\text{TV-STAR/AR}}$ are differences between the Akaike and Schwarz Information Criteria, respectively, of the estimated TV-STAR and the AR models. The numbers in parentheses following the test statistics are p-values.

The parameter estimates in (A.1) and the graphs in Figure A.2 show that the model captures the observed changes in the seasonal pattern. The misspecification tests of no remaining nonlinearity and parameter constancy reported in Table A.2 do not lead to rejections of their respective null hypotheses.

France

In the linear model for France, parameter constancy is rejected for both the seasonal dummies and the lagged first differences, although rejection is stronger for the deterministic terms. In a TV-AR model in which only the seasonal pattern is allowed to change, the misspecification tests still reject parameter constancy for the seasonal dummy coefficients rather strongly, while linearity of the autoregressive parameters also seems untenable. Sequentially including a second time-varying component for the dummies and a STAR component for the lagged dependent variables, we arrive at the following specification after recursively deleting insignificant coefficients:

$$\begin{aligned}
\Delta y_t = & -\underset{(1.13)}{4.81}\, D^*_{1,t} + \underset{(1.12)}{3.66}\, D^*_{2,t} - \underset{(0.51)}{21.8}\, D^*_{3,t} + \underset{(0.27)}{0.92}\, \Delta y_{t-1} - \underset{(0.44)}{1.83}\, \Delta y_{t-4} - \underset{(0.20)}{0.69}\, \Delta y_{t-5} \\
& + \underset{(0.43)}{1.86}\, \Delta y_{t-8} + (-\underset{(0.29)}{1.02} + \underset{(1.06)}{5.79}\, D^*_{1,t} - \underset{(0.61)}{3.32}\, D^*_{2,t}) \times G_1(t^*;\gamma_1,c_1) \\
& + (-\underset{(1.07)}{5.98}\, D^*_{1,t} + \underset{(1.04)}{11.4}\, D^*_{3,t}) \times G_2(t^*;\gamma_2,c_2) + (\underset{(0.24)}{1.50} - \underset{(0.27)}{0.92}\, \Delta y_{t-1} + \underset{(0.44)}{1.83}\, \Delta y_{t-4} \\
& + \underset{(0.20)}{0.69}\, \Delta y_{t-5} - \underset{(0.046)}{0.15}\, \Delta y_{t-6} - \underset{(0.43)}{1.86}\, \Delta y_{t-8}) \times G_3(\Delta_4 y_{t-1};\gamma_3,c_3) + \widehat{\varepsilon}_t, \qquad \text{(A.4)}
\end{aligned}$$

$$G_1(t^*;\gamma_1,c_1) = (1+\exp\{-\underset{(2.46)}{5.55}\,(t^* - \underset{(0.027)}{0.30})/\sigma_{t^*}\})^{-1}, \qquad \text{(A.5)}$$

$$G_2(t^*;\gamma_2,c_2) = (1+\exp\{-\underset{(1.21)}{2.57}\,(t^* - \underset{(0.026)}{0.58})/\sigma_{t^*}\})^{-1}, \qquad \text{(A.6)}$$

$$G_3(\Delta_4 y_{t-1};\gamma_3,c_3) = (1+\exp\{\underset{(-)}{-500}(\Delta_4 y_{t-1} + \underset{(0.024)}{2.53})/\sigma_{\Delta_4 y_{t-1}}\})^{-1}, \qquad \text{(A.7)}$$

$\widehat{\sigma}_\varepsilon = 1.43$, $\widehat{\sigma}_{\text{TV-STAR/AR}} = 0.74$, SK $= -0.10(0.31)$, EK $= 1.09(2.9\text{E}-3)$, JB $= 7.88(0.019)$, $\text{LM}_{\text{SC}}(1) = 0.72(0.40)$, $\text{LM}_{\text{SC}}(4) = 0.40(0.81)$, $\text{LM}_{\text{SC}}(12) = 1.37(0.19)$, ARCH(1) $= 0.25(0.61)$, ARCH(4) $= 3.21(0.52)$, $\text{AIC}_{\text{TV-STAR/AR}} = -0.46$, $\text{BIC}_{\text{TV-STAR/AR}} = -0.24$.

The model is made more parsimonious by imposing $\pm$ restrictions on the coefficients of Δy_{t-1}, Δy_{t-4}, Δy_{t-5}, and Δy_{t-8}, which are supported by the data. Because of these restrictions, the model does not contain any autoregressive dynamics when $G_3 = 1$, except for Δy_{t-6} which enters with a small coefficient. This means that the industrial production growth rate almost behaves like a white noise series during most of the time - note from panel (b) in Figure A.3 that G_3 only becomes zero during the most severe recessions that hit France during the sample period. As shown by the estimated intercepts and the coefficients on the seasonal dummies in (A.4), the first structural change involves a decline of the mean growth rate by 1.0% and affects the seasonal pattern only in the first and second quarter. By contrast, the second time-varying component captures changes in the first and third quarters which imply a large reduction of the amplitude of the seasonal cycle. See also Figure A.3.

Italy

For Italy, the strongest rejection occurs when constancy of the seasonal dummy parameters is tested against unspecified change, see Table 1. Misspecification tests of a TV-AR model in which only the seasonal dummy coefficients are time-varying still reject constancy of the dummy coefficients. Adding a second TV-AR component, we find strong evidence against parameter constancy of the coefficients of the lagged first differences. Allowing these to be time-varying as well, we cannot reject the hypothesis that the change in the autoregressive dynamics and the first change in the seasonal pattern occur simultaneously. Furthermore, we find that exclusion restrictions on the autoregressive parameters implying that the combined parameter equals zero when $G_1 = 1$ cannot be rejected. This means that the industrial production growth rate is a white noise series with seasonal means after the first smooth transition has been completed. The estimated model has the form

$$\begin{aligned}\Delta y_t = \; & \underset{(0.36)}{2.01} + \underset{(0.46)}{1.99}\, D^*_{1,t} + \underset{(1.05)}{4.75}\, D^*_{2,t} - \underset{(0.59)}{13.1}\, D^*_{3,t} + \underset{(0.083)}{0.18}\, \Delta y_{t-2} - \underset{(0.093)}{0.48}\, \Delta y_{t-5} - \underset{(0.094)}{0.35}\, \Delta y_{t-6} \\ & + (-\underset{(0.43)}{1.59} - \underset{(1.08)}{3.49}\, D^*_{2,t} - \underset{(0.81)}{8.77}\, D^*_{3,t} - \underset{(0.083)}{0.18}\, \Delta y_{t-2} + \underset{(0.093)}{0.48}\, \Delta y_{t-5} + \underset{(0.094)}{0.35}\, \Delta y_{t-6}) \times G_1(t^*; \gamma_1, c_1) \\ & (-\underset{(0.77)}{2.04}\, D^*_{1,t} + \underset{(0.80)}{3.90}\, D^*_{3,t}) \times G_2(t^*; \gamma_2, c_2) + \widehat{\varepsilon}_t, \end{aligned} \tag{A.8}$$

$$G_1(t^*; \gamma_1, c_1) = (1 + \exp\{-\underset{(3.73)}{9.43}\,(t^* - \underset{(0.014)}{0.39})/\sigma_{t^*}\})^{-1}, \tag{A.9}$$

$$G_2(t^*; \gamma_2, c_2) = (1 + \exp\{-\underset{(-)}{101}(t^* - \underset{(0.023)}{0.81})/\sigma_{t^*}\})^{-1}, \tag{A.10}$$

$\widehat{\sigma}_\varepsilon = 2.05$, $\widehat{\sigma}_{\text{TV-STAR/AR}} = 0.80$, SK $= 0.14(0.24)$, EK $= 0.38(0.17)$, JB $= 1.41(0.49)$, $\text{LM}_{\text{SC}}(1) = 0.30(0.58)$, $\text{LM}_{\text{SC}}(4) = 0.55(0.70)$, $\text{LM}_{\text{SC}}(12) = 0.83(0.61)$, ARCH$(1) = 13.9(1.9\text{E}-4)$, ARCH$(4) = 16.9(2.0\text{E}-3)$, $\text{AIC}_{\text{TV-STAR/AR}} = -0.35$, $\text{BIC}_{\text{TV-STAR/AR}} = -0.21$.

The estimates of the seasonal dummy coefficients in (A.8) and the graphs in Figure A.4 clearly show that the deviations from the mean growth rate in the first and second quarters have declined during the second half of the 1970s, whereas the seasonal pattern in the third and fourth quarters has been amplified.

__**United States**__

For the US, constancy of the seasonal dummy coefficients and linearity of the autoregressive parameters are rejected. Starting with a STAR model allowing for nonlinearity in the coefficients of the lagged first differences only and using $\Delta_4 y_{t-2}$ as transition variable (rejection of linearity is strongest in this case), the hypothesis of constancy of the dummy coefficients is no longer rejected at conventional significance levels. Hence, we arrive at the STAR model

$$\begin{aligned}\Delta y_t = {} & \underset{(0.16)}{0.44}\, D^*_{2,t} + \underset{(0.066)}{0.37}\, \Delta y_{t-1} - \underset{(0.095)}{0.41}\, \Delta y_{t-2} - \underset{(0.068)}{0.46}\, \Delta y_{t-5} - \underset{(0.14)}{0.68}\, \Delta y_{t-7} + (\underset{(0.26)}{0.49} \\ & + \underset{(0.095)}{0.41}\, \Delta y_{t-2} + \underset{(0.095)}{0.41}\, \Delta y_{t-4} + \underset{(0.071)}{0.25}\, \Delta y_{t-6} + \underset{(0.16)}{0.54}\, \Delta y_{t-7}) \times G_1(\Delta_4 y_{t-2}; \gamma_1, c_1) + \widehat{\varepsilon}_t,\end{aligned} \tag{A.11}$$

$$G_1(\Delta_4 y_{t-2}; \gamma_1, c_1) = (1 + \exp\{-\underset{(-)}{59.0}\, (\Delta_4 y_{t-2} - \underset{(0.23)}{0.95})/\sigma_{\Delta_4 y_{t-2}}\})^{-1}, \tag{A.12}$$

$\widehat{\sigma}_\varepsilon = 1.34$, $\widehat{\sigma}_{\text{TV-STAR/AR}} = 0.89$, SK $= -0.48(8.0\text{E}-3)$, EK $= 1.80(2.6\text{E}-6)$, JB $= 26.6(1.7\text{E}-6)$, $\text{LM}_{\text{SC}}(1) = 3.99(0.048)$, $\text{LM}_{\text{SC}}(4) = 1.31(0.27)$, $\text{LM}_{\text{SC}}(12) = 1.07(0.39)$, ARCH(1) $= 0.18(0.67)$, ARCH(4) $= 10.0(0.040)$, $\text{AIC}_{\text{TV-STAR/AR}} = -0.20$, $\text{BIC}_{\text{TV-STAR/AR}} = -0.16$.

Note that a $\pm$ restriction on the coefficients of Δy_{t-2} is imposed. A similar restriction on the coefficients of Δy_{t-7} is rejected. The skewness and excess kurtosis of the residuals are caused entirely by the observations for 1975.1 and 1980.2, where large negative residuals occur.

Table A.1: Testing linearity and parameter constancy in STAR/TV-AR models

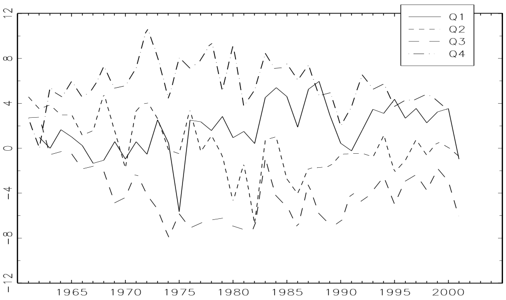
Transition variable	STAR		TV-AR		TV-STAR	
	LM_1	LM_3	LM_1	LM_3	LM_1	LM_3
Canada						
$s_t = \Delta_4 y_{t-3}$	0.13	0.62	0.23	1.4E−4	0.34	0.40
France						
$s_t = t^*$	0.46	0.20	0.38	0.015	0.48	0.073
Germany						
$s_t = \Delta_4 y_{t-1}$	0.51	0.61	7.6E−3	9.4E−4	0.42	0.27
Italy						
$s_t = t^*$	0.47	0.58	0.26	8.8E−3	0.64	0.26
Japan						
$s_t = \Delta_4 y_{t-1}$	0.17	0.046	0.024	2.4E−6	0.033	0.11
United Kingdom						
$s_t = t^*$	0.041	0.063	0.21	0.32	0.081	0.056
United States						
$s_t = \Delta_4 y_{t-2}$	0.064	0.10	0.11	0.32	0.057	0.51

Notes: The table contains p-values of F-variants of the LM_k, $k = 1, 3$, tests of linearity of the seasonal pattern within the STAR model (7) for quarterly industrial production growth rates, where the delay parameter l is assumed unknown but restricted to be less than or equal to 4. The null hypotheses of the different tests are linearity conditional on parameter constancy [STAR], constancy conditional on linearity [TV-AR], and linearity and constancy [TV-STAR].

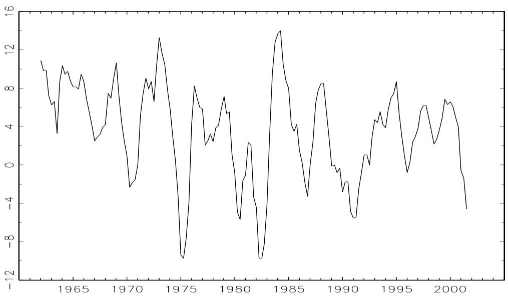
Table A.2: Diagnostic tests of parameter constancy and no remaining nonlinearity in TV-STAR models

Transition	$D_{s,t}$		Δy_{t-j}		σ_ε^2	
variable	LM_1	LM_3	LM_1	LM_3	LM_1	LM_3
Canada						
t	0.47	0.34	0.58	0.87	0.70	0.27
$\Delta_4 y_{t-1}$	0.39	0.88	0.60	0.34	0.14	0.36
$\Delta_4 y_{t-2}$	0.61	0.96	0.43	0.87	0.20	0.54
$\Delta_4 y_{t-3}$	0.88	0.93	0.76	0.74	0.35	0.71
$\Delta_4 y_{t-4}$	0.83	0.90	0.53	0.64	0.47	0.46
France						
t	0.67	0.18	0.23	0.45	0.79	0.83
$\Delta_4 y_{t-1}$	0.69	0.77	0.47	0.23	0.92	0.43
$\Delta_4 y_{t-2}$	0.74	0.72	0.83	0.40	0.57	0.75
$\Delta_4 y_{t-3}$	0.91	0.75	0.65	0.39	0.71	0.88
$\Delta_4 y_{t-4}$	0.80	0.48	0.93	0.63	0.99	0.85
Italy						
t	0.71	0.90	0.39	0.92	0.20	0.019
$\Delta_4 y_{t-1}$	0.85	0.88	0.17	0.51	0.35	0.46
$\Delta_4 y_{t-2}$	0.86	0.89	0.39	0.72	0.13	0.30
$\Delta_4 y_{t-3}$	0.51	0.93	0.27	0.84	0.097	0.35
$\Delta_4 y_{t-4}$	0.55	0.89	0.50	0.53	0.37	0.84
United States						
t	0.43	0.62	0.52	0.81	0.27	0.038
$\Delta_4 y_{t-1}$	0.83	0.25	0.60	0.91	0.11	0.26
$\Delta_4 y_{t-2}$	0.70	0.84	0.75	0.60	0.34	0.75
$\Delta_4 y_{t-3}$	0.98	0.18	0.78	0.58	0.41	0.75
$\Delta_4 y_{t-4}$	0.64	0.038	0.80	0.60	0.55	0.84

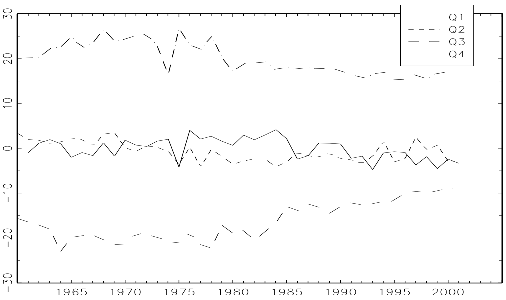
Notes: The table contains p-values of F-variants of LM diagnostic tests of parameter constancy (rows labelled t) and no remaining nonlinearity (rows labelled $\Delta_4 y_{t-l}$, with $l = 1, \ldots, 4$) of seasonal dummy coefficients (columns headed $D_{s,t}$), autoregressive parameters (columns headed Δy_{t-j}), and residual variance (columns headed σ_ε^2) in estimated TV-STAR models for quarterly industrial production growth rates.



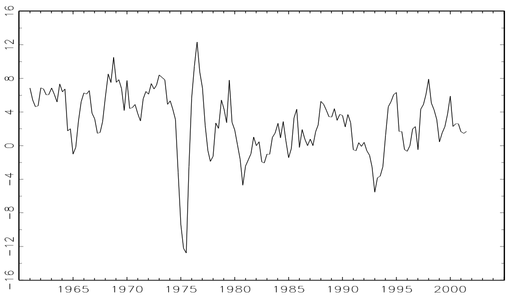
(a) Canada - First difference per quarter



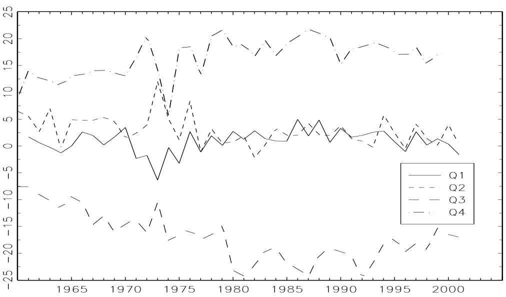
(b) Canada - Seasonal difference



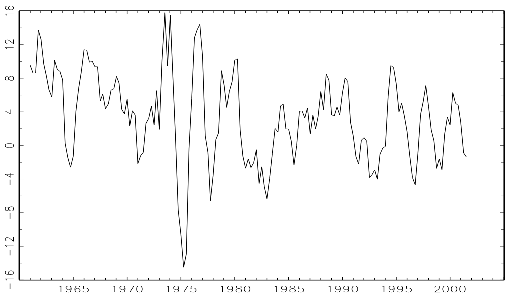
(c) France - First difference per quarter



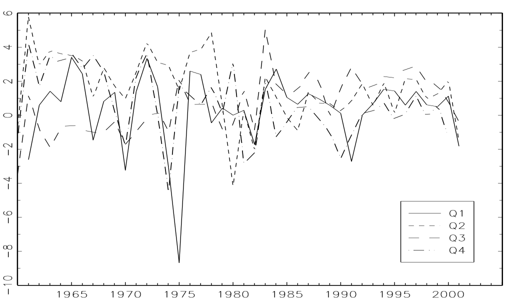
(d) France - Seasonal difference



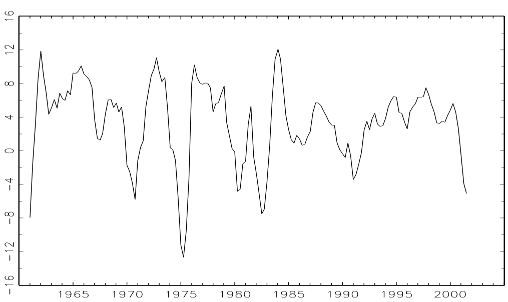
(e) Italy - First difference per quarter



(f) Italy - Seasonal difference

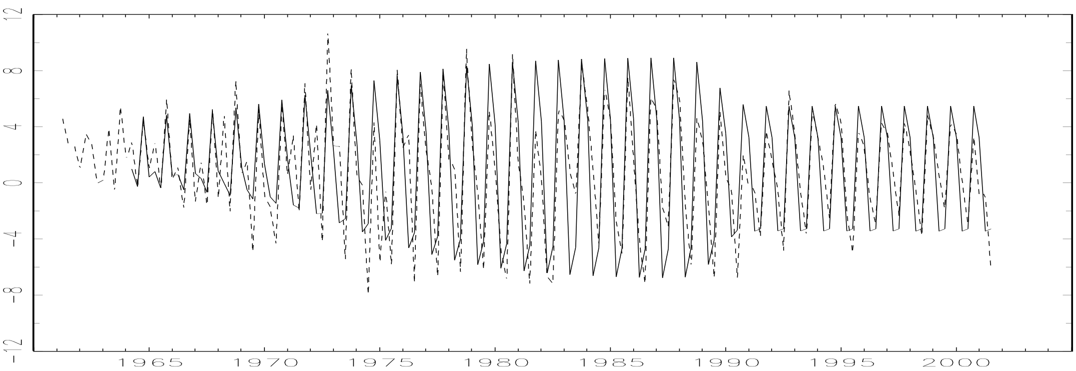


(g) US - First difference per quarter

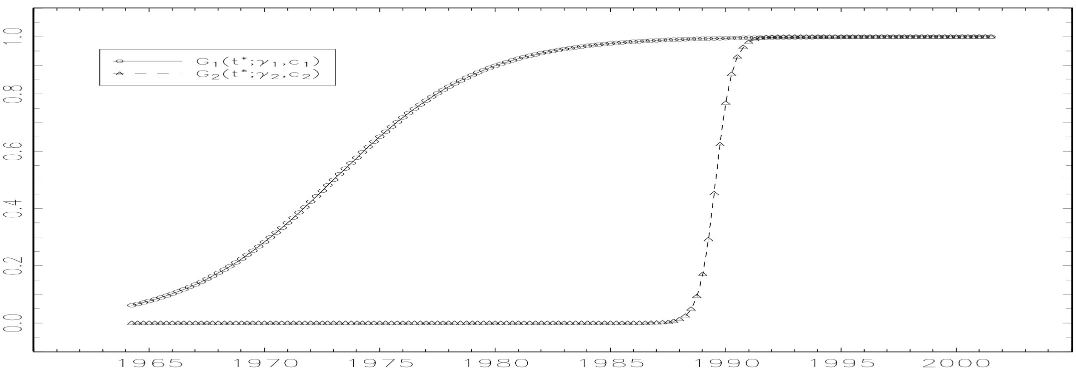


(h) US - Seasonal difference

Figure A.1: Industrial production for Canada, France, Italy and the US

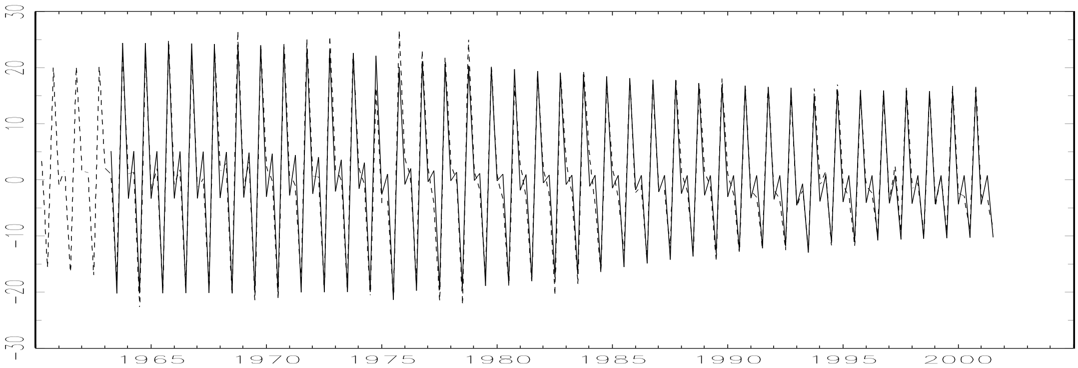


(a) First difference (dashed line) and deterministic seasonal component in TV-STAR model (solid line)

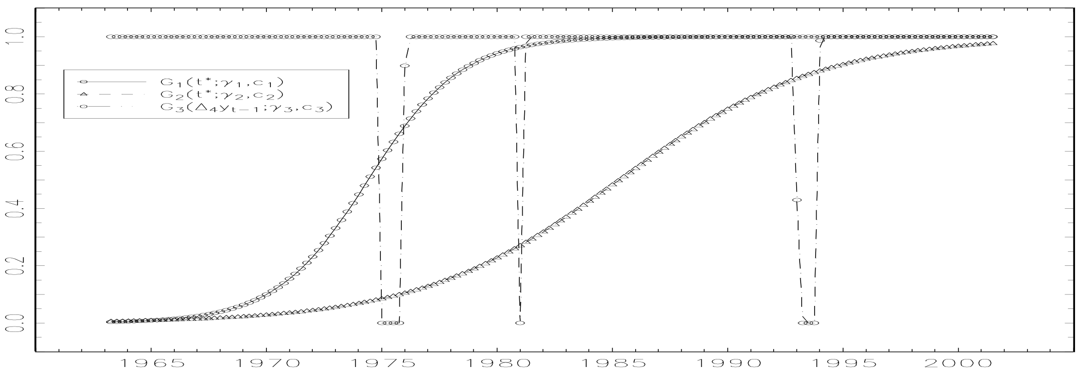


(b) Transition functions in TV-STAR model

Figure A.2: Characteristics of TV-STAR model for quarterly industrial production growth rates in Canada as given in (A.1).

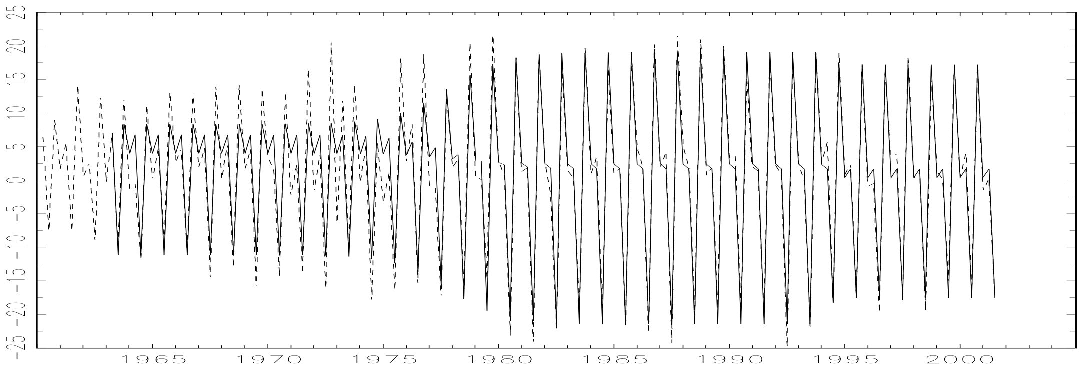


(a) First difference (dashed line) and deterministic seasonal component in TV-STAR model (solid line)

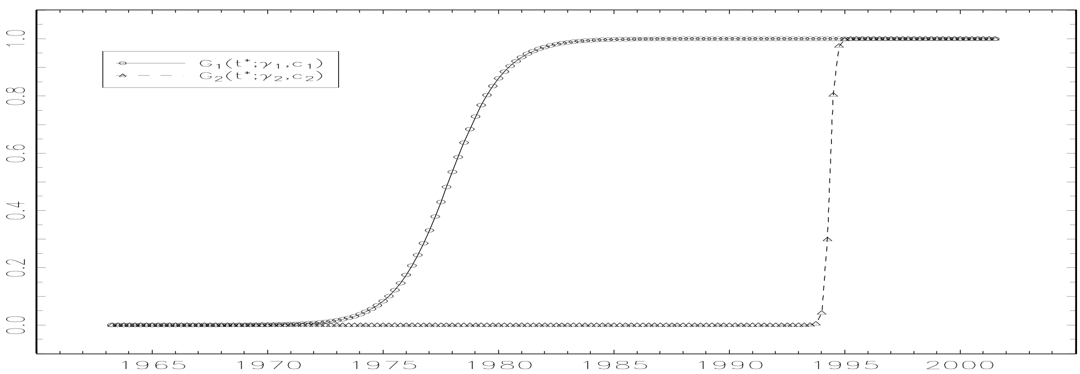


(b) Transition functions in TV-STAR model

Figure A.3: Characteristics of TV-STAR model for quarterly industrial production growth rates in France as given in (A.4).

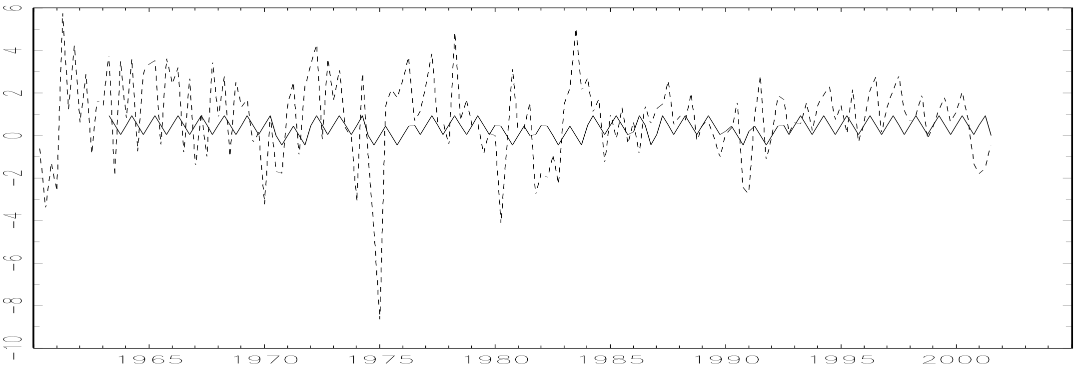


(a) First difference (dashed line) and deterministic seasonal component in TV-STAR model (solid line)

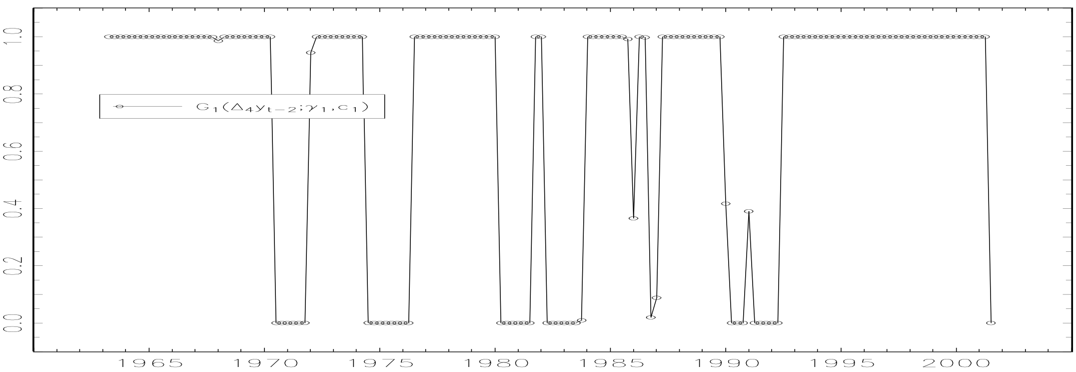


(b) Transition functions in TV-STAR model

Figure A.4: Characteristics of TV-STAR model for quarterly industrial production growth rates in Italy as given in (A.8).



(a) First difference (dashed line) and deterministic seasonal component in TV-STAR model (solid line)



(b) Transition functions in TV-STAR model

Figure A.5: Characteristics of TV-STAR model for quarterly industrial production growth rates in the US as given in (A.11).