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the case of natural and synthetic rubber prices

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Abstract

Prices on commodity markets are often correlated because they react to similar cycles in the economy. This is especially true for commodities which are inputs into the same products. And even more so for commodities which are considered here as partial substitutes. Prices of such commodities are considered to be highly correlated.

This paper investigates the leads and lags in prices for natural rubber (**NR**) and synthetic rubber (**SR**). It concludes that prices of **NR** lead prices of **SR** by about three to six months, depending on the country concerned. This influence is, however, changing over time, as can be estimated when using the Kalman filter approach for a model with time-varying parameters. The relationships are reducing in significance over time: both positive and negative coefficients tend to zero, implying that both markets are increasingly separated. The influence of demand on the other hand remains quite stable. A notable exception is the EU. The two markets, **NR** and **SR**, are increasingly insulated and the consumption side continues to play a steady and significant role.

1 Introduction

Regarding commodity price developments the general assumption is that the price of a commodity is determined by supply and demand, while in turn influencing supply and demand. An interesting set of questions arises when two or more commodities are considered for which market developments may interact. This is the case if the buyers or sellers of the individual commodities influence each other. Two commodities which are inputs into the same production process and which are at least partially substitutes form a special case of this subject. An example is the rubber market where natural rubber (**NR**) and synthetic rubber (**SR**) are both used in numerous applications, with the tyre sector taking by far the largest share of the market.

Some decades ago it was believed that **NR** and **SR** both had a reasonable share of the market to themselves for technological reasons, while leaving a large share open to substitution for price reasons; see Allen et al. (1973). However, technology has advanced and competition is claimed by many to have been replaced by complementarity. This would mean that the relationship between the prices of **NR** and **SR**, if any, must have reduced in importance: the markets would then be increasingly insulated. Burger and Smit (1994, forthcoming) expect a shortage of **NR**, especially because of the very limited substitutability of **NR** by currently available types of **SR**.

However, Jumpasut (1995) claims that the ease with which a significant change in the composition of an **NR/SR** blend formulation can be made is often under-estimated. Even for products which are the subject of specifications, health and safety or product liability conditions, it is sometimes possible to make changes in the **NR/SR** ratio of up

to 20%. Higher levels of substitution will take place only when manufacturers expect the change in relative prices to continue for some period of time. However, the price of natural rubber is important in determining discounts of premium against synthetic rubber list prices. Jumpasut states that the sharp increases of the SBR price during 1994-1995 was partially influenced by the sharp increase in natural rubber prices. When the NR-price increases, SR producers will see an opportunity to raise their prices as well.

In this article we investigate the relationship between the prices of NR and SR. Monthly figures are used because most of the dynamics have faded away when using annual figures. The disadvantage of using monthly data is that no realistic structural model can be developed on a monthly basis, because of lack of adequate and accurate data. Only a reduced form is used. The main research themes are: is there any relationship, which is the direction of the causality, what are the leads and lags, and, are the relationships changing over time. A consequence of such a changing relationship can be the variability of the parameters of the model during the sample period. This is analyzed by using a Kalman filter procedure. See Harvey (1990) and Steyn (1996) for a thorough discussion of the Kalman filter. Examples of Kalman-filter applications can e.g. be found in Cuthbertson et al. (1992) and in Merckies and Steyn (1994) who studied a changing lag pattern, caused by economic activity, in the relation between housing starts and actual production of houses in The Netherlands.

2 Analysis of the data

2.1 The prices

Description

In Figure 1 the time-series data of the natural rubber (P_t^{nr}) and synthetic rubber (P_t^{sr, r_i}) prices are plotted. P_t^{nr} refers to a market price for a particular grade: Ribbed Smoked Sheets grade 1 (RSS1), Singapore, converted into US\$. P_t^{sr, r_i} is the export-unit value of synthetic rubber in region r_i . The regions that are considered are the USA, the EU (with the %-price in Germany) and Japan. Time-series data for the period 1982(01) - 1996(02) are collected from the Rubber Statistical Bulletin of the International Rubber Study Group.

The first thing that strikes in Figure 1 is the difference in the movements of the price of NR and SR. This is a data phenomenon because of a difference of the definitions in the prices series. The pattern in the NR-price is smooth compared to the price series for SR because of the homogeneity of the grade and presumably more 'smooth' behaviour of traders in agreeing on a certain price on a particular market as compared to SR exporters not knowing the 'market', trading bilaterally and varying mixtures of types and grades. While all SR-prices (export unit values) are converted into US\$, developments over time are quite different: peaks and troughs do not fully coincide and are not of the same magnitude; besides, at first sight, the pattern in Japan appears to be slightly smoother, perhaps indicating a more homogeneous composition of exports.

To get more insight in the time-series properties of the prices, a preparative analysis of the data has been performed, like unit-root tests, causality tests etc. The results of these tests are presented below.

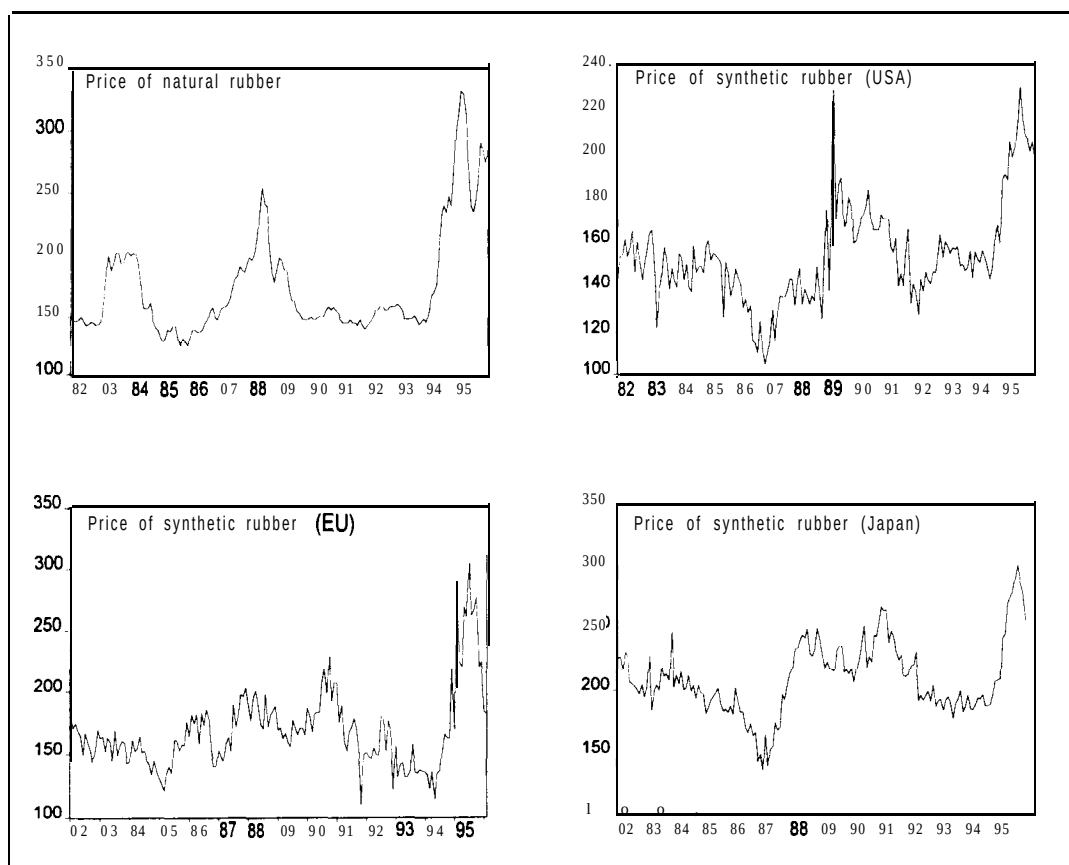


Figure 1: Prices of natural and synthetic rubber

Order of integration

The order of integration has been tested by using the Augmented Dickey-Fuller test (ADF-test). In Table 1 the results of the ADF-tests are given, showing that all the variables are I(1).

Commodity	y_t	∇y_t
	ADF	ADF
Natural rubber price	-1.65	-7.91
Synthetic rubber price USA	-2.30	-4.45
Synthetic rubber price EU	-2.90	-4.35
Synthetic rubber price Japan	-2.69	-4.09
5% critical value: -3.52		

Table 1: Unit-root tests

Causality

Factors in the economy, be it rubber related, vehicle related or more general will influence the development of prices. Such influences will become apparent more quickly on a physical market than in export unit values, contracts for which may have been concluded some time before. For that reason it is reasonable to suggest that the price of natural rubber is the leading price in the market. It is interesting to apply

Granger causality tests to check this hypothesis. The tests have been computed by using 12 lags. First possible Granger causality between the synthetic rubber prices only, has been checked. This is not the case, the null hypothesis of no-Granger causality is not rejected at the 5% level. Granger causality between the price of natural rubber and the synthetic rubber prices does exist, and becomes stronger in more recent years. The results, with various starting dates, are given in Table 2. In the tables * and ** indicate a significance level of 5% and 1%, as usual.

$H_0 :$	$p^{nr} \xrightarrow{not} p^{sr,EU}$		$p^{nr} \xrightarrow{not} p^{sr,Japan}$		$p^{nr} \xrightarrow{not} p^{sr,USA}$	
Starting date	F-value	p-value	F-value	p-value	F-value	p-value
1982.01	3.24	0.00**	1.92	0.03*	0.91	0.54
1989.01	3.75	0.00**	2.03	0.04'	0.85	0.60
1990.01	3.95	0.00**	1.61	0.12	2.51	0.01''
1991.01	5.13	0.00**	2.19	0.03'	2.23	0.03*

Table 2: Results of the Granger causality tests

Because of the results of the Granger causality tests, cross correlations between the price of natural rubber and the prices of synthetic rubber have been computed to get more insight in the dynamics of the relations between these prices. The coefficients mostly are not significantly different from zero after about 7 lags. In Table 3 some results for a recent subperiod, 1990(01) - 1996(02), are summarized.

	EU		Ja in		USA	
1	P_t^{nr}, P_{t-i}^{sr}	P_t^{nr}, P_{t+i}^{sr}	P_t^{nr}, P_{t-i}^{sr}	P_t^{nr}, P_{t+i}^{sr}	P_t^{nr}, P_{t-i}^{sr}	P_t^{nr}, P_{t+i}^{sr}
0	-0.09	-0.09	0.01	0.01	-0.01	-0.01
1	0.11	0.05	-0.14	0.10	-0.05	-0.02
2	-0.05	*0.15	-0.01	*0.17	0.06	-0.05
3	0.02	*-0.15	-0.11	**0.33	0.08	**0.24
4	0.06	**0.30	-0.01	*0.16	-0.01	*0.16
5	*-0.12	0.11	-0.08	*0.21	-0.11	0.09
6	-0.01	*0.15	*-0.13	*0.18	*-0.17	**0.26
7	-0.05	**0.26	-0.09	0.06	-0.01	*0.15

Table 3: Cross-correlation coefficients between the prices of natural rubber and synthetic rubber, se = 0.12

The coefficients in the first column under each country are low and mostly negative, implying that **SR** prices do not lead **NR**-prices. The correlations show significant values when the price of natural rubber is leading, up to six or seven months in advance. There appears not to be any contemporaneous effect, which may be caused by the time required for delivery as mentioned above.

2.2 The demand variables

Above has been clearly shown that **NR**-prices influence **SR** prices with a lag of a number of months. The opposite is not true. Because of this causality, the price of **SR** is the dependent variable. The other possibly influential factors are supply and demand. Supply of **NR** cannot be relevantly included as explanatory variable in this connection. Representative and relevant data about supply of **SR** are not available:

production is adjusted to demand. Therefore only total rubber demand may usefully be incorporated. In Figure 2 the graphs of the demand variables are shown.

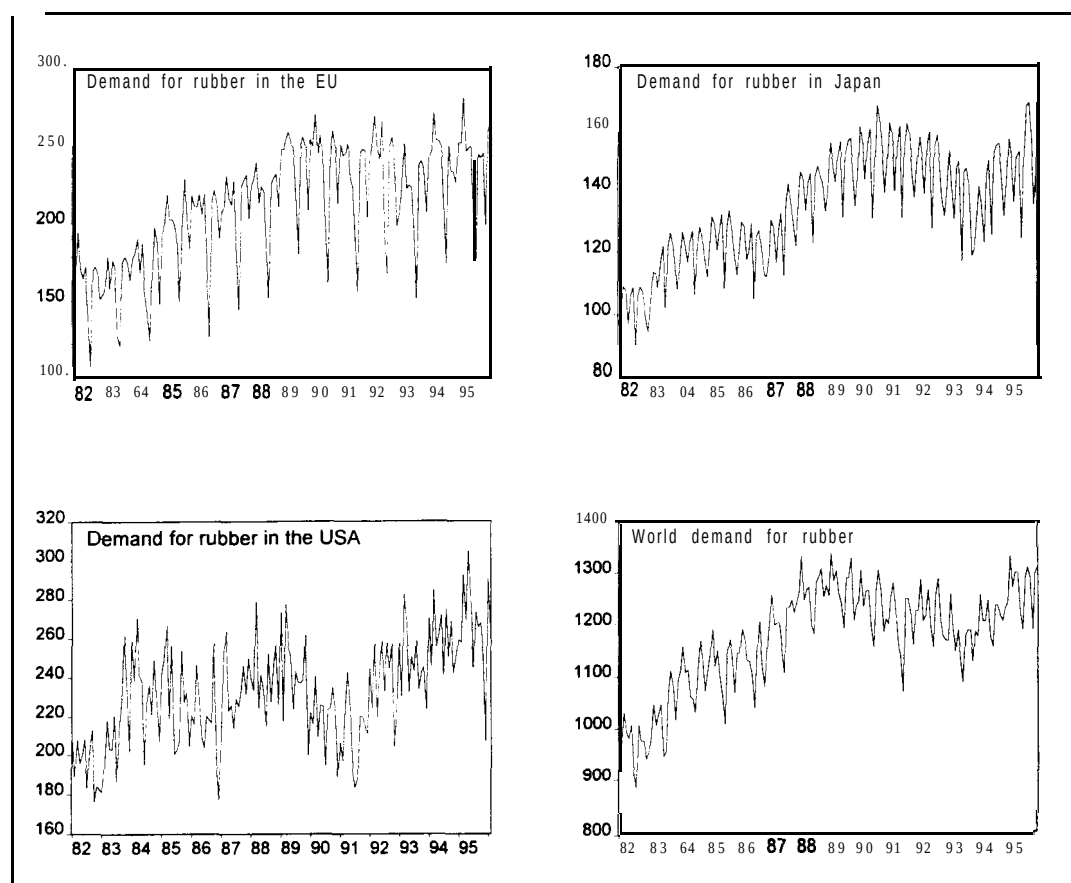


Figure 2: Rubber demand in main regions

The recession in rubber demand started in 1989 in the USA, with recovery commencing as early as 1992. This recessionary period occurred a few years later in Japan and the EU, with the latter showing more a levelling off with little recovery. The other striking phenomenon in Figure 2 is the possibility of seasonality in the series. Computation of the autocorrelation functions for the demand variables indicates seasonality in the demand for rubber in the EU and in Japan, whereas it is hardly present in the data for the demand in the USA. This is obvious from Table 4.

Lag	EU	Japan	USA
12	0.81	0.87	0.30
24	0.72	0.79	0.35
36	0.67	0.72	0.26

Table 4: Seasonal autocorrelations

The autocorrelations for the other frequencies are small. The type of seasonality indicates an additive seasonal pattern.

Order of integration

As for the prices, the order of integration of the demand variables was tested. The ADF-values are reported in Table 5.

Commodity	y_t	∇y_t
	ADF	ADF
Demand EU	-1.69	-8.88
Demand Japan	-2.56	-8.81
Demand USA	-2.54	-9.38
Total demand	-2.64	-10.19
5% critical value:		-3.52

Table 5: Unit-root tests

According to the ADF-test the variables are I(1), which is obvious from Table 5.

3 The model

3.1 The specification with fixed parameters

As mentioned when discussing the specification of the model in verbal terms as spelled out in the previous sections, it is the intention to estimate and analyse the relationship between the prices of natural and synthetic rubber, and to include the demand for rubber as an important explanatory variable. The model will be used to analyse the structure between the prices. In the previous section it was shown how the prices are related. In this section the stability of the structure among the prices during the sample period will be tested.

A simple specification of the model is just the linear dynamic relationship between these variables (in logs):

$$P_t^{sr,r_i} = \beta_0 + \sum_{i=1}^p \beta_i P_{t-i+1}^{nr} + \sum_{j=1}^q \gamma_j CT_{t-j+1}^{r_i} + u_t, \text{ with } u_t \sim NID(0, \sigma_u^2). \quad (1)$$

The variables have the following interpretation:

P_t^{sr,r_i} : the price of synthetic rubber in region r_i ;

P_t^{nr} : the price of natural rubber;

$CT_t^{r_i}$: the demand for rubber in the same region r_i or ‘total demand’.

As the NR-price behaves differently from the SR-prices before 1985, due to a boom in the price of natural rubber during the years ‘83 – ‘84 because of, most likely, the new and untested influence of the presence of the International Natural Rubber Agreement, the sample period 1985(01) - 1996(02) is used to test the relationships. The inclusion of the demand variables in the equations reduces the variance of the residuals substantially compared to equations without these variables. Therefore only results with the demand variables included in the model are considered in this paper.

Simple OLS estimation of the parameters of equation (1) results in residuals which are highly autocorrelated, e.g. the Ljung-Box Q-statistics, computed up to 12 lags, often accumulate to values in the hundreds! Therefore the parameters of this relationship are suspected not to be fixed during the sample period, which was the idea behind this research project. This hypothesis is tested in the next section.

3.2 The specification with variable parameters

In this section the parameters are allowed to vary during the sample period. Model (1) is written in the state-space form: a measurement equation for the relationship between the variables and a transition equation for the changing parameters. The simplest model in state-space form with time-dependent parameters and variables is as follows.

Measurement equation:

$$P_t^{sr, r_i} = \beta_{t0} + \sum_{i=1}^p \beta_{ti} P_{t-i+1}^{nr} + \sum_{j=1}^q \gamma_{tj} CT_{t-j+1}^{r_i} + u_t, \text{ with } u_t \sim NID(0, \sigma_u^2), \quad (2)$$

transition equations:

$$\begin{aligned} \beta_{ti} &= \beta_{t-1,i} + \eta_{ti}, \text{ with } \eta_{ti} \sim NID(0, \sigma_{\eta_i}^2) \\ \gamma_{tj} &= \gamma_{t-1,j} + \vartheta_{tj}, \text{ with } \vartheta_{tj} \sim NID(0, \sigma_{\vartheta_j}^2). \end{aligned}$$

The transition equations allow the parameters to follow a random walk. The estimation of the parameters in equation (2) is done by using a Kalman filter procedure.

The numerical estimates and their graphs are presented in the Appendix. In this section the estimation results are evaluated, first more generally and after that by region.

General

Using the Kalman filter approach eliminates the residual autocorrelation largely or even completely, while the parameter estimates become significantly different from zero. The appropriate number of lags has to be determined empirically. The results are very sensitive to the number of lags. Inclusion of too many or too few lags and the use of seasonally adjusted demand variables produces substantial autocorrelation.

The estimation results for the parameters presented in the Appendix give the values reached at the end of the sample period. Proxies for the estimates of σ_{η_i} and σ_{ϑ_j} are also reported. The ‘residuals’ of the transition equations have been computed as $\hat{\beta}_{ti} - \hat{\beta}_{t-1,i}$ and $\hat{\gamma}_{tj} - \hat{\gamma}_{t-1,j}$, which can be considered as proxies for the residuals because they have not been corrected for the different information that has been used to estimate $\beta_{ti}(\gamma_{tj})$ and $\beta_{t-1,i}(\gamma_{t-1,j})$. In most cases we observe that the standard errors of the β s are larger than the standard errors of the γ s, which is an indication that the β s are more variable than the γ s.

P-values are given in parentheses. *LB(p)* and *JB* refer to the Ljung-Box autocorrelation test for *p*th-order autocorrelation and the Jarque-Bera normality test respectively. In order not to disturb the graphs of the estimated parameters by the starting values of the procedure, the presentation starts from 1989(1). Sometimes we present graphs of the individual parameters and sometimes one graph for all the parameters. The choice depends on which graph is the most informative one.

USA

World demand and USA demand for rubber have been tried as explanatory variables. Best results were obtained using the Kalman filter for $p = 6$ and $q = 5$ combined with the world demand variable. This produces less autocorrelation compared to including USA rubber demand. The estimation results are shown in Table 6

and the graphs of the parameter estimates in Figures 3 and 4 in the Appendix. The equations are estimated for the period 1985(01) - 1996(02).

The parameters β_i for the effect of the price of **NR** on the price of **SR** (Figure 3) tend to move towards zero while not reaching it, except β_4 (no change) and β_5 (very small change). The largest change can be seen for β_2 increasing from -1.8 to -1.2. Then follow β_1 declining from around 1.7 to around 1.4, β_6 declining from around 1.4 to around 1.2 and β_3 declining from around 0.6 to around 0.4. Finally, β_7 increases from -1.0 to -0.7.

Such a strong pattern cannot be seen for the γ_i . All parameter estimates (see Figure 4) are positive with only γ_3 showing a strong decline of 0.3 while the decline in the other parameters ranges between zero ($\gamma_1, \gamma_2, \gamma_4$) and 0.1 (γ_5 and γ_6). This development shows that the influence of consumption on the price of **SR** has not changed much.

EU

The best results are obtained using the Kalman filter approach with six lags for both explanatory variables, the price of **NR** and in this case EU rubber consumption. See the results for the parameter estimates in Table 7 and Figures 5 and 6. The results are mostly even more significant than in the case of the USA. The estimates for the β_i are rather large. Apart from β_7 all price coefficients tend towards zero, be it from the positive or from the negative side. Most parameters show a reaction after the price jump in 1994 - 1995. Contrary to the case of the USA the coefficients of EU rubber consumption tend to slightly move towards zero. The sum of the coefficients declines over time. This may imply that the European market becomes less relevant. Again, the price jump of 1994 - 1995 pushes the γ_i upwards.

Japan

In the relationship explaining the price of **SR** in Japan, two lags of the endogenous variable had to be included to eliminate residual autocorrelation. The coefficients of the lagged dependent variable $P_{t-i}^{sr,ri}$ are indicated with α_i for $i \in \{1, 2, \dots\}$. Estimates of the parameters are in the Appendix, Table 8, while the patterns over time are presented in the Figures 7, 8 and 9. Again for most price parameters the same conclusions can be drawn: a movement towards zero. Notable exceptions are: β_4 (different direction) and β_5 and β_6 (little change apart from the first year or so). It is clear that again the pattern during the first year shown is somewhat out of range. The coefficients for CT_t move in various directions, not necessarily towards zero. The sum of the coefficients roughly stays at the same level, until 1993, the year of the start of the recovery (see Figure 1).

4 Conclusion

What is the relationship between the prices of **NR** and **SR**? Using monthly figures because most of the dynamics have faded away when using annual figures, the following conclusions can be drawn:

- indeed there is a relationship; the causality is from the price of **NR** to the price of **SR**;
- the price of **NR** leads with some three to six months;

- there is a significant influence, but only when the model is specified in such a way that the relationships is allowed to change over time and is estimated using the Kalman filter;
- the price coefficients in general tend towards zero;
- the model includes the total rubber consumption, the coefficients of which remain rather constant or decline slightly over time.

More verbally: the two markets, **NR** and **SR**, are increasingly insulated and the consumption side continues to play a steady and significant role.

Appendix with the estimation results

USA

Coefficient	estimate	standard error	$\hat{\sigma}_{\eta_i}$ or $\hat{\sigma}_{\vartheta_i}$	statistics
β_0	-19.25	4.26		$\hat{\sigma}_u = 0.0067$ $DW = 2.30$ $LB(12) = 20.12(0.07)$ $JB = 3.00(0.22)$
β_1	1.41	0.21	0.041	
β_2	-1.22	0.21	0.018	
β_3	0.38	0.19	0.013	
β_4	0.64	0.23	0.041	
β_5	-0.33	0.14	0.010	
β_6	1.21	0.13	0.009	
β_7	-0.67	0.14	0.024	
γ_1	0.67	0.15	0.025	
γ_2	0.09	0.19	0.038	
γ_3	0.77	0.19	0.034	
γ_4	0.44	0.19	0.036	
γ_5	0.26	0.13	0.012	
γ_6	0.08	0.12	0.014	

Table 6: Final Kalman-filter estimation results for the USA

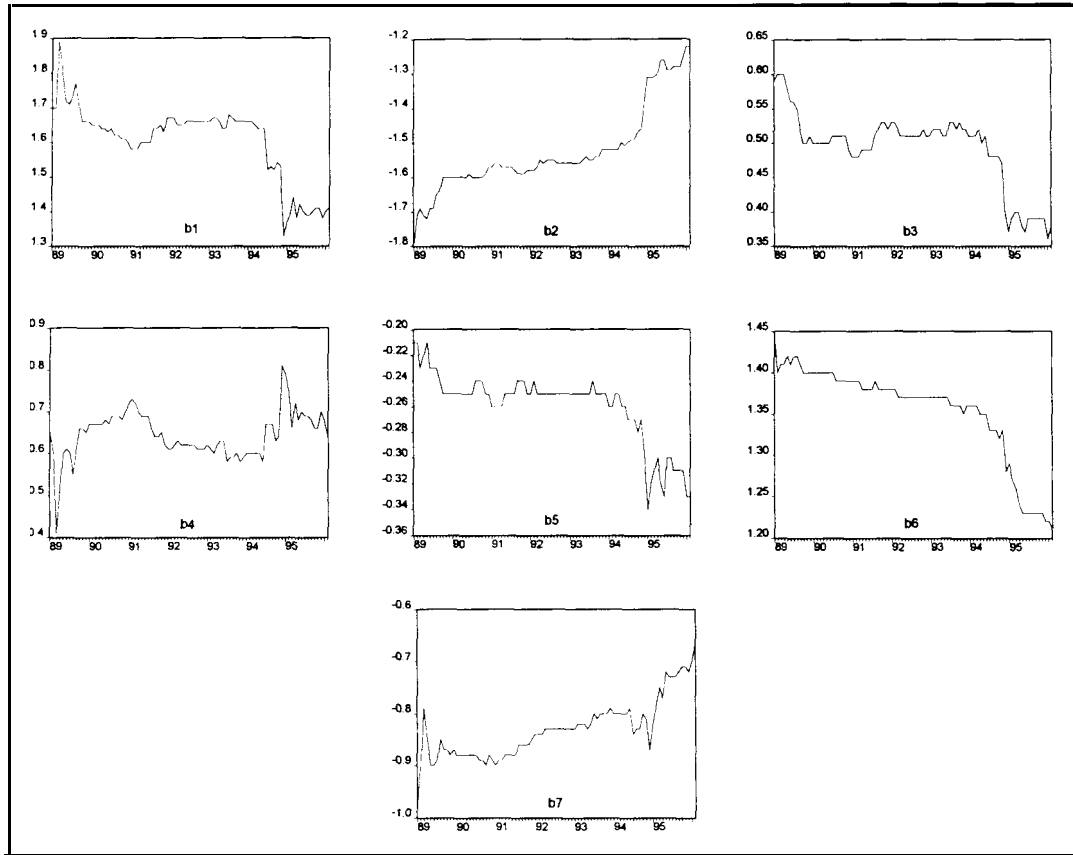


Figure 3: Pattern of the parameters β_i of P_{t-i}^{nr} for the USA since 1989

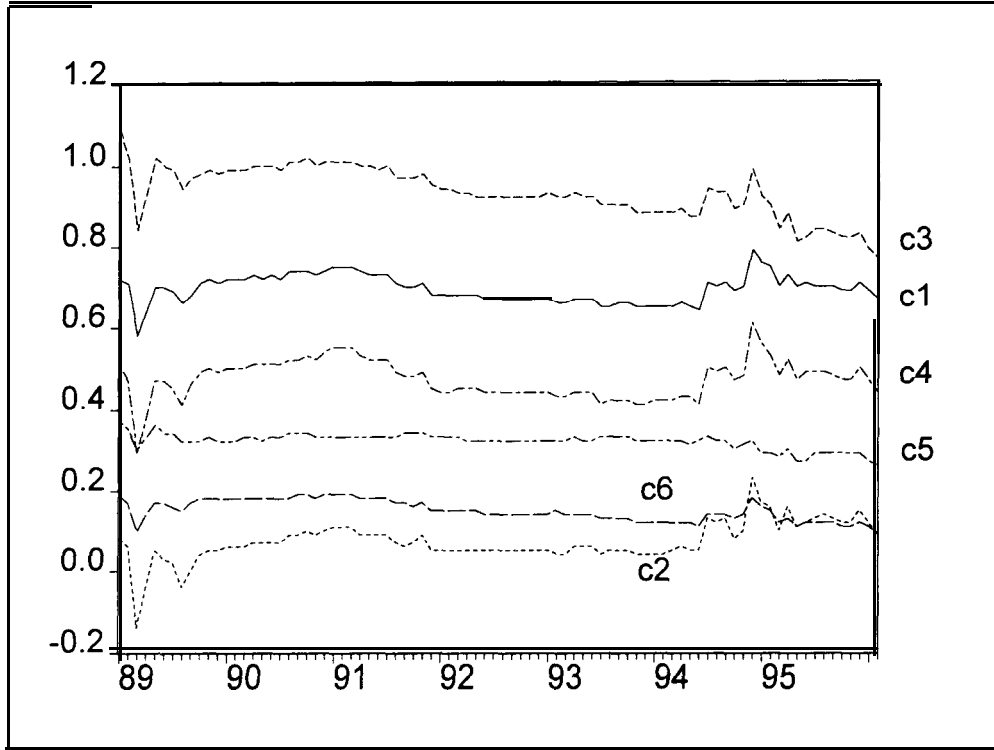


Figure 4: Pattern of the parameters γ_i of CT_t^{USA} since 1989

The *EU*

Coefficient	estimate	standard error	$\hat{\sigma}_{\eta_i}$ or $\hat{\sigma}_{\vartheta_i}$	statistics
β_0	17.72	7.47		$\hat{\sigma}_u = 0.018$ $DW = 1.60$ $LB(12) = 18.43(0.10)$ $JB = 187.9(0.00)$
β_1	-1.67	0.54	0.051	
β_2	0.45	0.64	0.058	
β_3	-1.76	0.56	0.033	
β_4	0.49	0.54	0.031	
β_5	0.54	0.51	0.054	
β_6	-0.26	0.40	0.034	
β_7	-1.12	0.39	0.029	
γ_1	0.07	0.21	0.017	
γ_2	0.13	0.22	0.017	
γ_3	0.24	0.24	0.021	
γ_4	0.43	0.26	0.028	
γ_5	0.10	0.23	0.018	
γ_6	0.24	0.20	0.015	
γ_7	-0.09	0.19	0.011	

Table 7: Final Kalman-filter estimation results for the EU

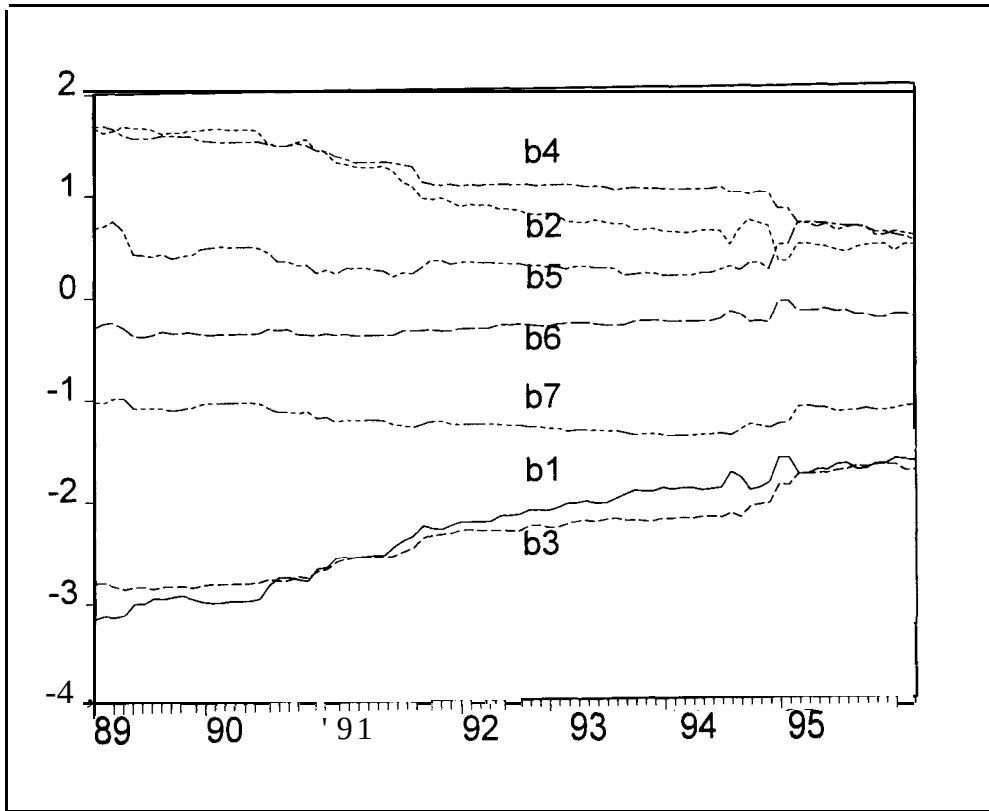


Figure 5: Pattern of the parameters $\beta_i P_{t-i}^{nr}$ for the EU since 1989

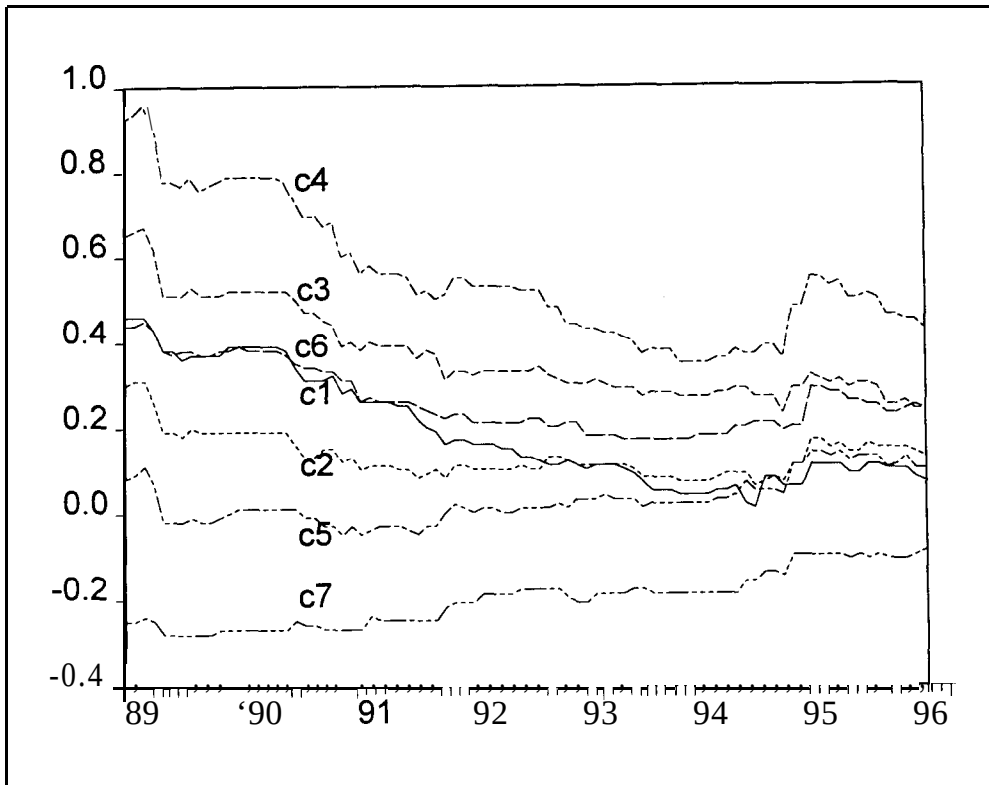
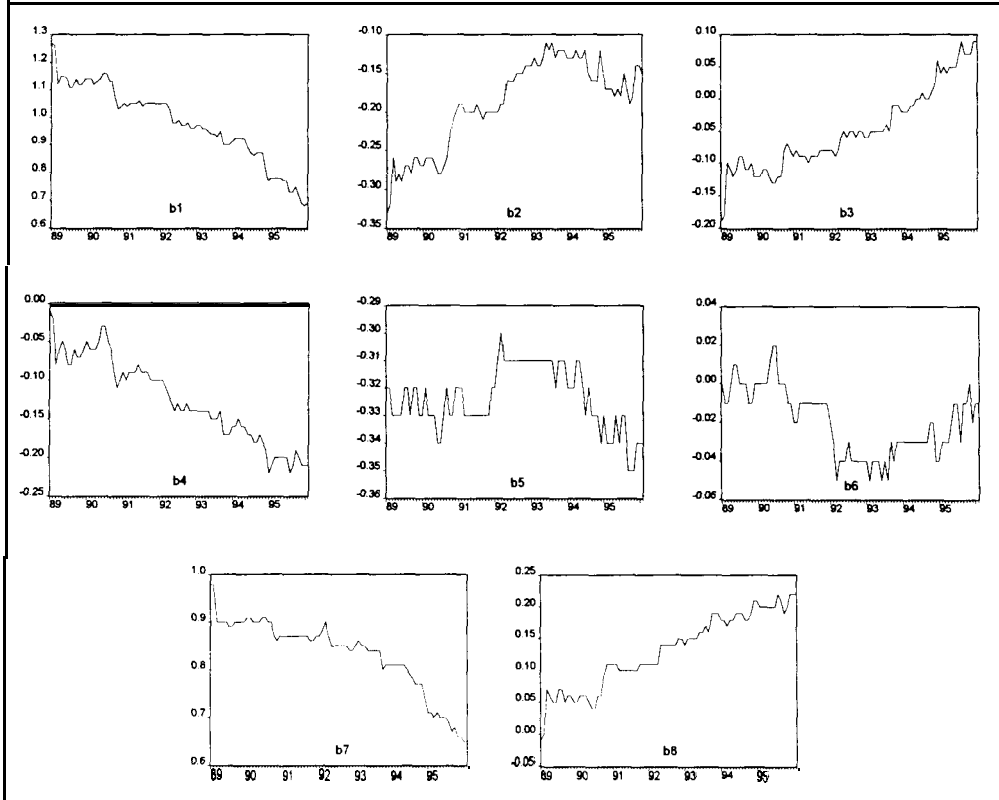


Figure 6: Pattern of the parameters γ_i of $\mathcal{C}T_t^{EV}$ since 1989

Coefficient	estimate	standard error	$\hat{\sigma}_{\eta_i}$ or $\hat{\sigma}_{\vartheta_i}$	statistics
β_0	-16.52	2.85		$\hat{\sigma}_u^2 = 0.0075$ $DW = 1.87$ $LB(12) = 16.78(0.16)$ $JB = 695.9(0.00)$
β_1	0.68	0.22	0.026	
β_2	-0.15	0.23	0.016	
β_3	0.09	0.20	0.016	
β_4	-0.21	0.19	0.013	
β_5	-0.34	0.16	0.007	
β_6	-0.01	0.17	0.008	
β_7	0.65	0.17	0.014	
β_8	0.21	0.15	0.014	
γ_1	0.15	0.09	0.007	
γ_2	0.10	0.08	0.005	
γ_3	0.60	0.10	0.008	
γ_4	0.37	0.11	0.006	
γ_5	0.75	0.10	0.005	
γ_6	0.44	0.12	0.009	
γ_7	0.42	0.10	0.005	
γ_8	0.22	0.09	0.004	
α_1	0.05	0.12	0.006	
α_2	0.22	0.13	0.011	

Table 8: Final Kalman-filter estimation results for Japan

Figure 7: Pattern of the parameters β_i of P_{t-i}^{nr} for Japan since 1989

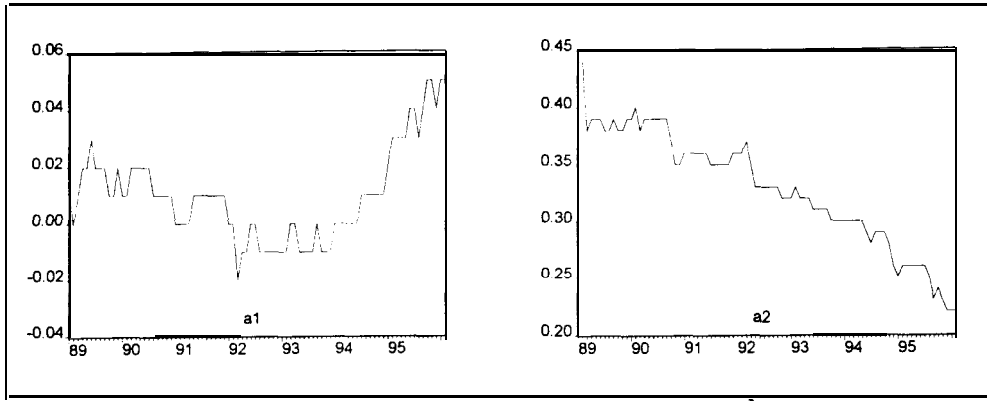


Figure 8: Pattern of the parameters of the lagged $P_{t-i}^{sr, Japan}$ since 1989

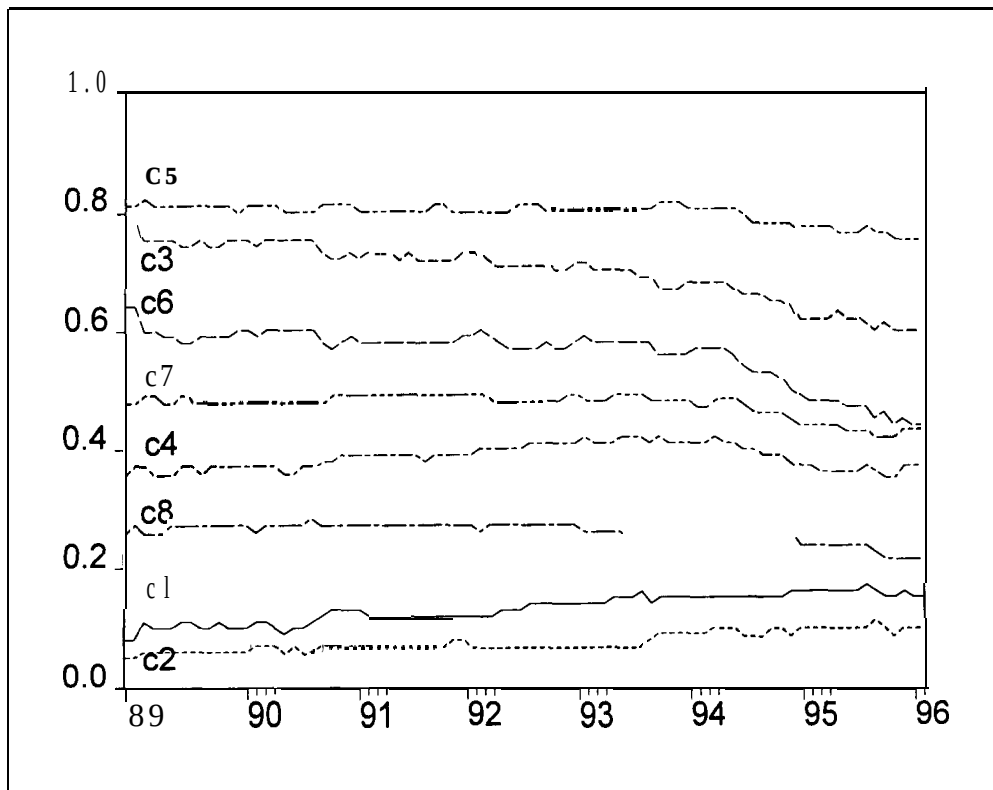


Figure 9: Pattern of the parameters γ_i of CT_t^{Japan} since 1989

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