New score-driven models for trimming and Winsorizing: An application for Guatemalan Quetzal to US Dollar

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Motivation

The GTQ/USD exchange rate time series involve a stochastic annual seasonality component, which is due to the seasonality of export incomes from agricultural goods.

The main agricultural products exported from Guatemala are:

coffee, sugar, banana and cardamom

For the harvest period of these products, when export income in USD enters Guatemala, the GTQ becomes stronger with respect to USD. After the finish of those exports GTQ becomes weaker with respect to USD.

Statistics	GTQ/USD p_t	GTQ/USD $\ln(p_t/p_{t-1})$	Month	Mean p_t
Start date	4 January 1994	4 January 1994	January	7.4087
End date	30 June 2017	30 June 2017	February	7.3819
Sample size	6,128	6,128	March	7.3590
Minimum	5.4939	−0.0199	April	7.3545
Maximum	8.3948	0.0192	May	7.3411
Average	7.3904	0.0000	June	7.3712
Standard deviation	0.7476	0.0017	July	7.3656
Skewness	−1.2354	0.6494	August	7.3840
Excess kurtosis	0.0049	14.8366	September	7.4312
ADF statistic, constant	−2.1142(0.2391)	−13.6809***(0.0000)	October	7.4501
ADF statistic, constant plus trend	−0.8073(0.9637)	NA	November	7.4298
ADF statistic, constant plus quadratic trend	−2.2003(0.7293)	NA	December	7.4126

Fig. 1(a) p_t from 6 Nov 1989 to 31 Dec 1993

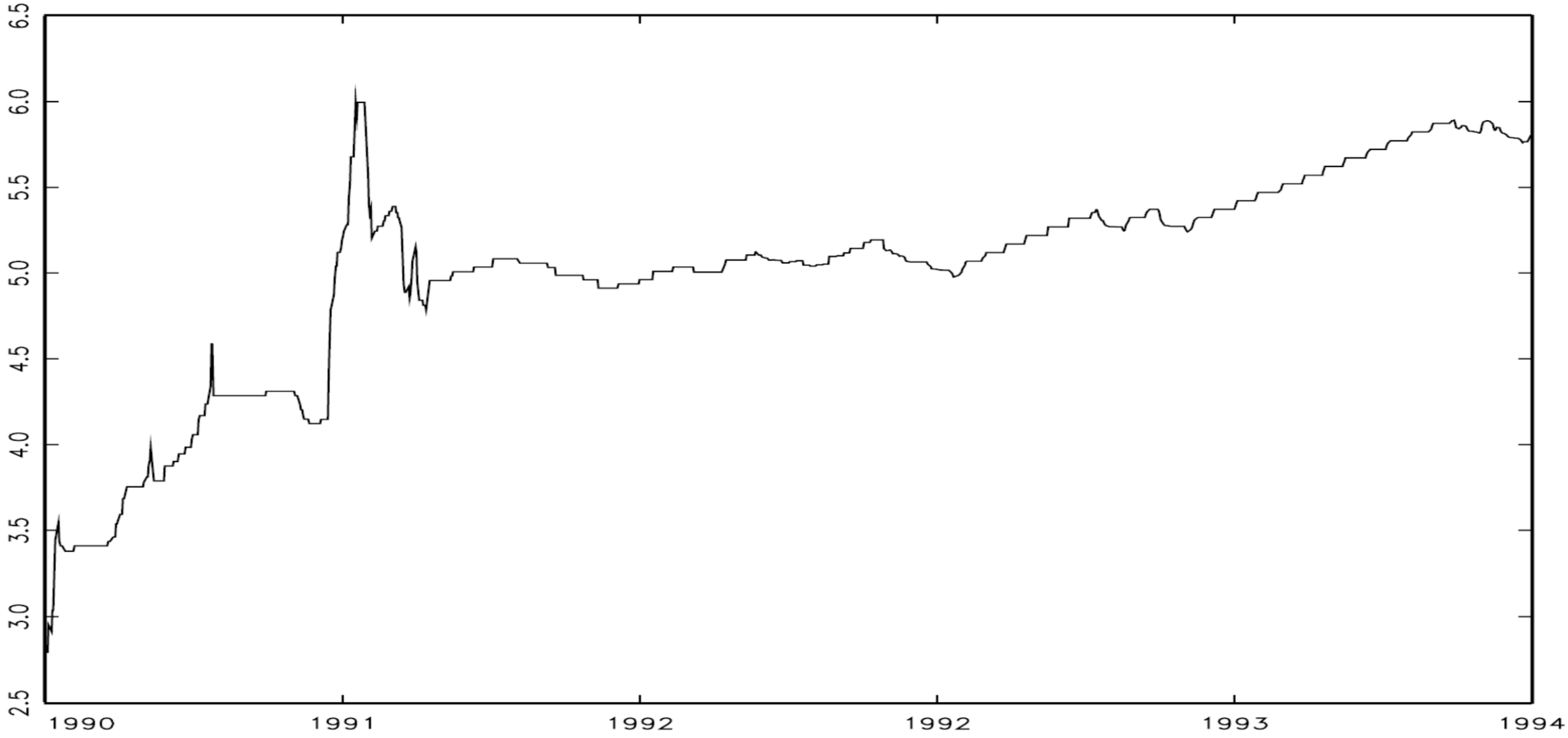


Fig. 1(b) $\ln(p_t/p_{t-1})$ from 6 Nov 1989 to 31 Dec 1993

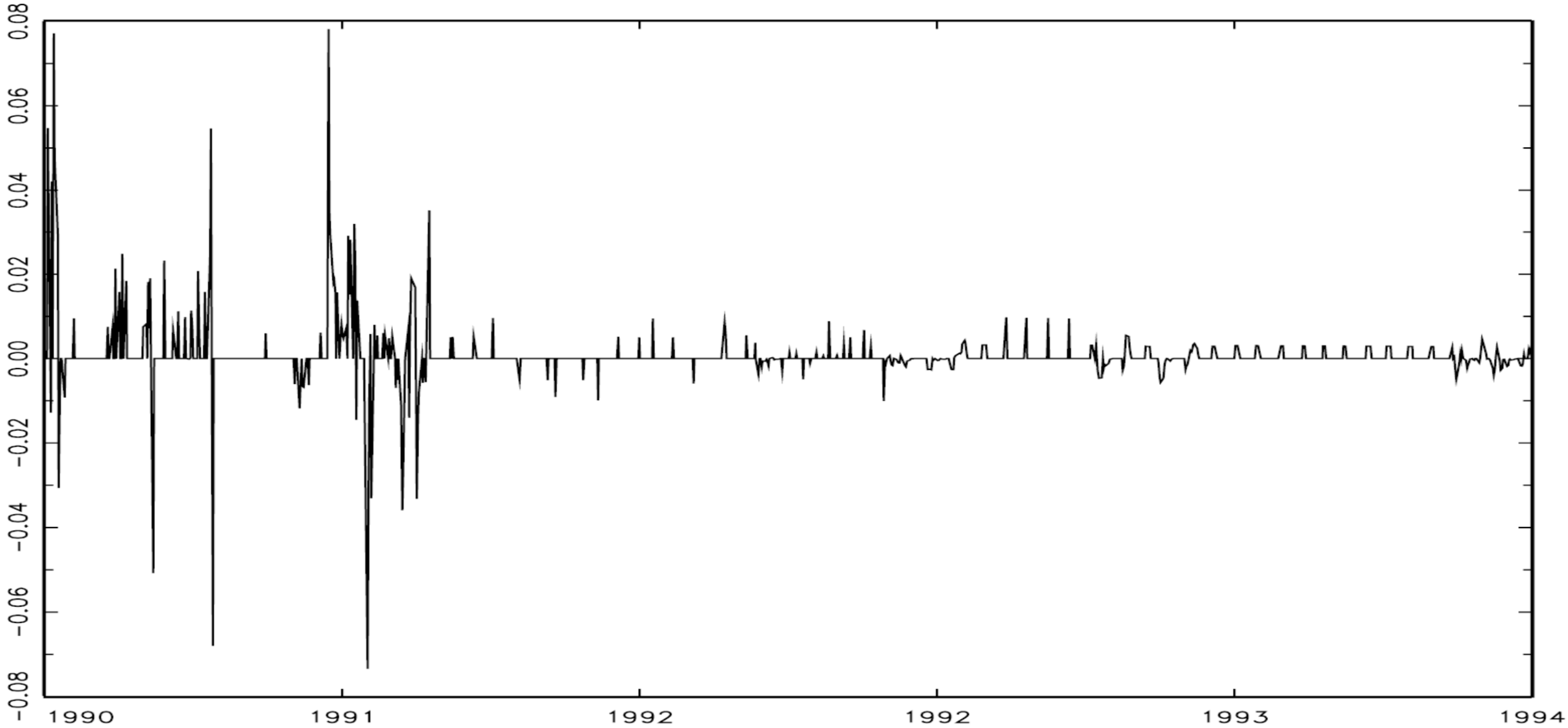
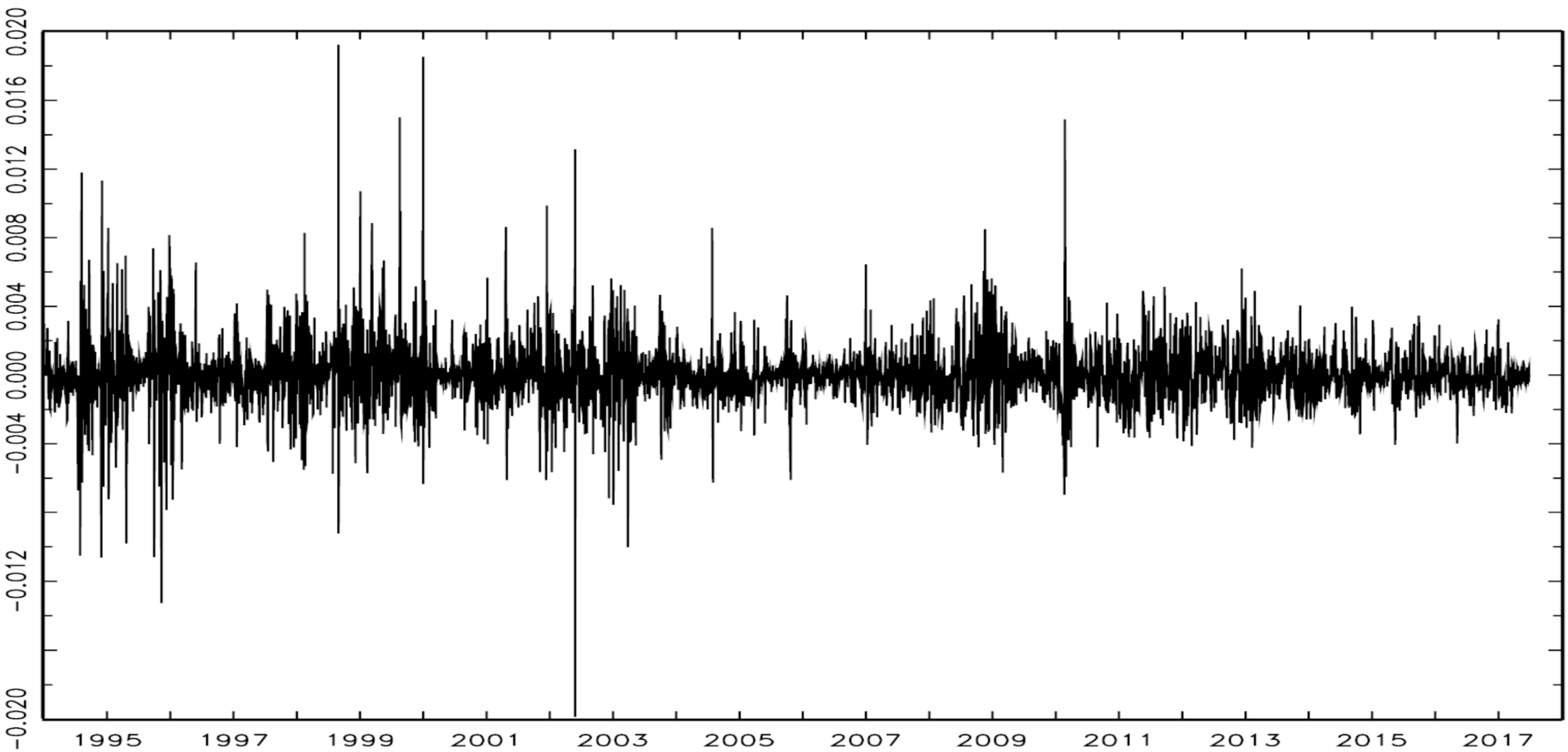
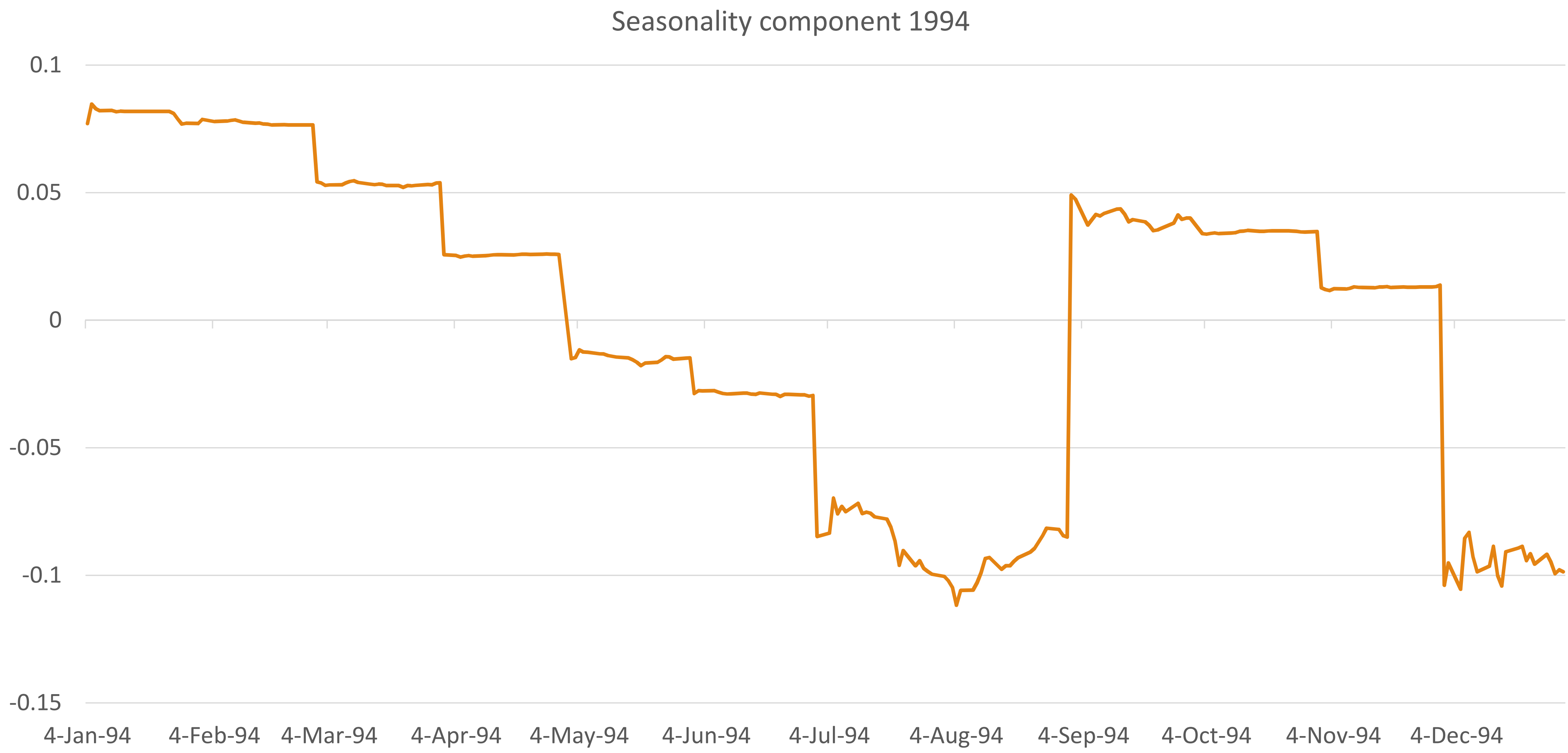
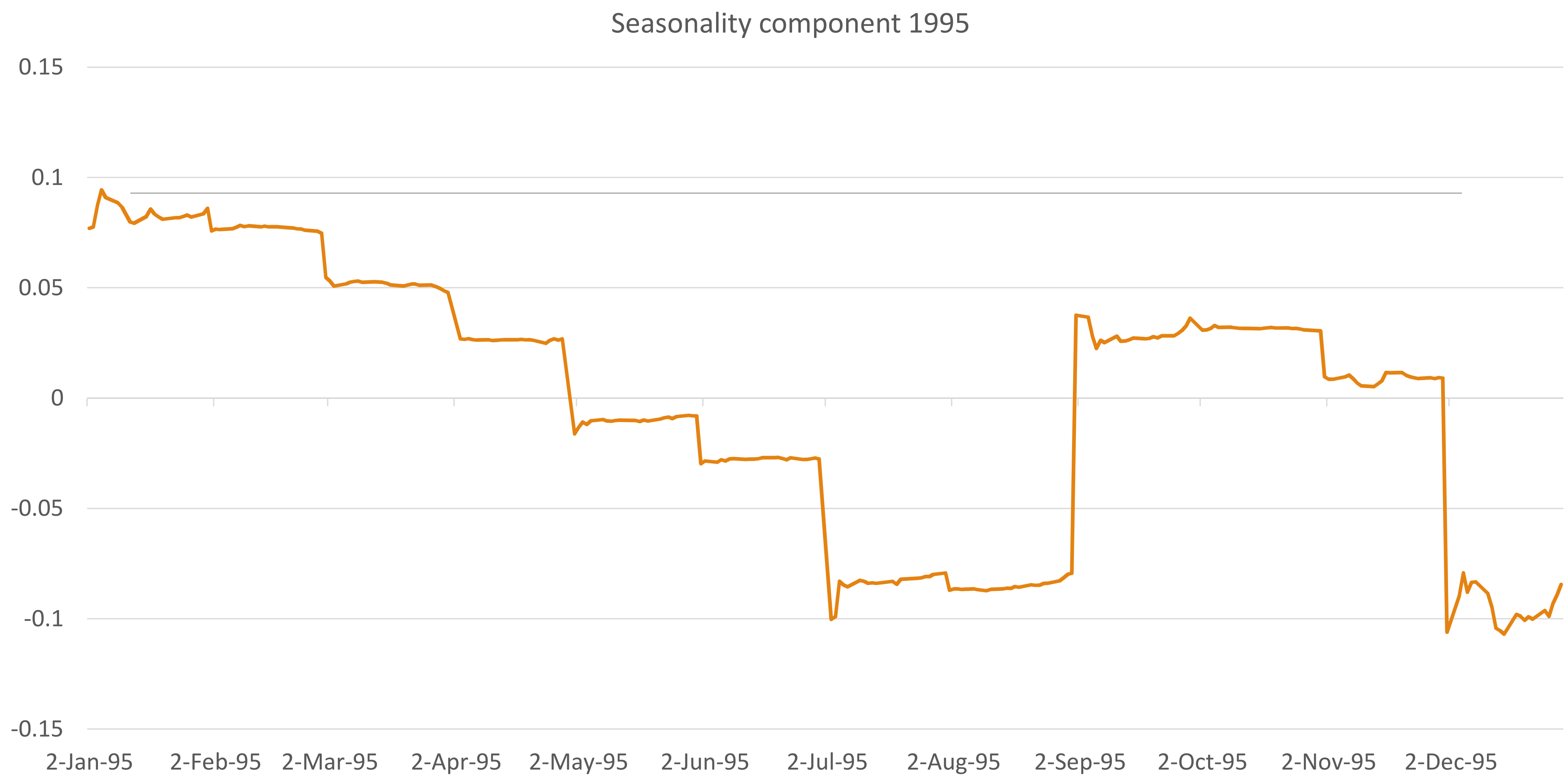


Fig. 1(c) p_t from 4 Jan 1994 to 30 Jun 2017

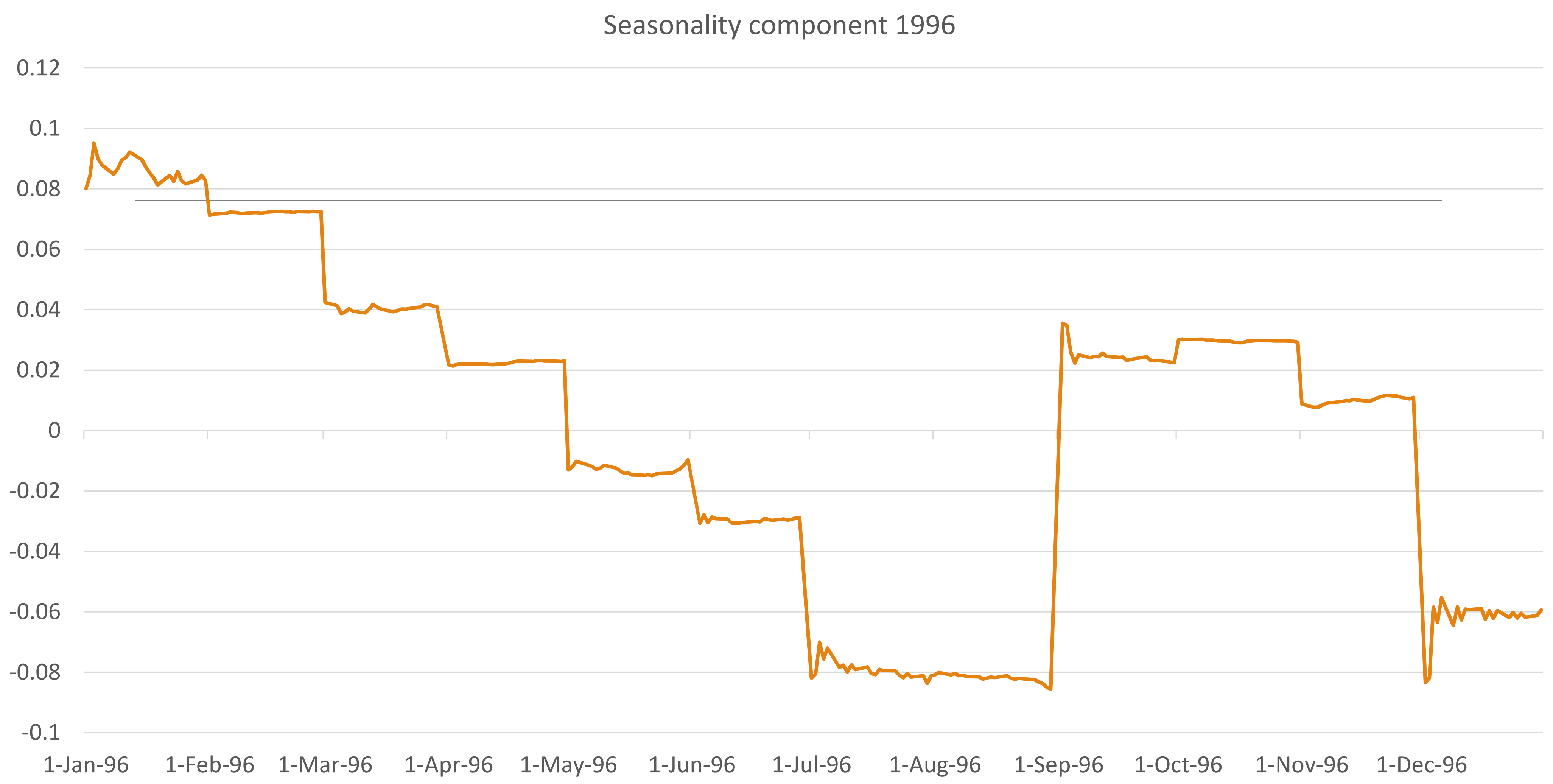
Fig. 1(d) $\ln(p_t/p_{t-1})$ from 4 Jan 1994 to 30 Jun 2017

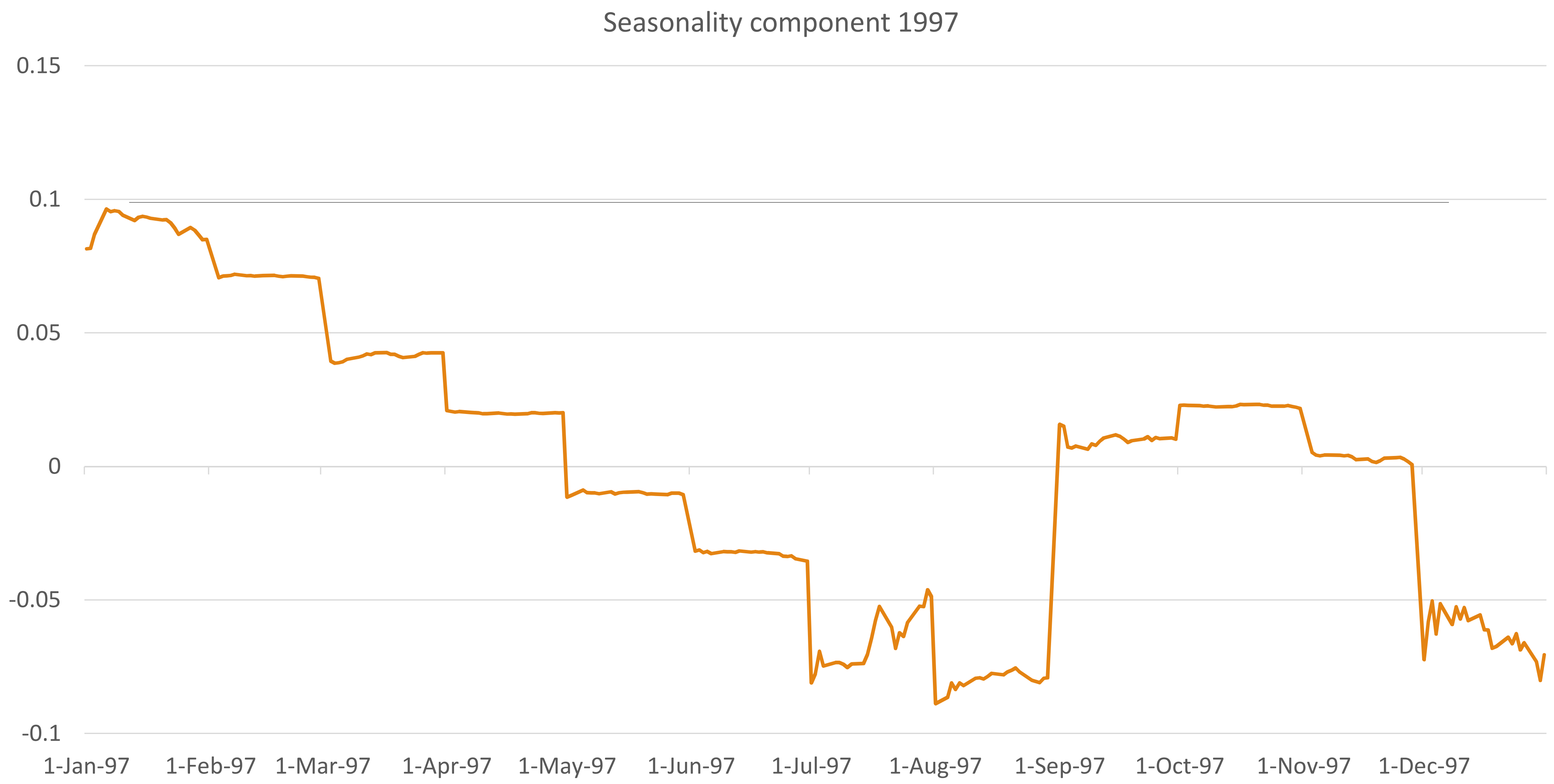



Seasonality component 1994
0.1
0.05
0
-0.05
-0.1
-0.15
4-Jan-94
4-Feb-94
4-Mar-94
4-Apr-94
4-May-94
4-Jun-94
4-Jul-94
4-Aug-94
4-Sep-94
4-Oct-94
4-Nov-94
4-Dec-94



Seasonality component 1995
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
2-Jan-95
2-Feb-95
2-Mar-95
2-Apr-95
2-May-95
2-Jun-95
2-Jul-95
2-Aug-95
2-Sep-95
2-Oct-95
2-Nov-95
2-Dec-95


Seasonality component 1996
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
1-Jan-96
1-Feb-96
1-Mar-96
1-Apr-96
1-May-96
1-Jun-96
1-Jul-96
1-Aug-96
1-Sep-96
1-Oct-96
1-Nov-96
1-Dec-96


Seasonality component 1997
0.15
0.1
0.05
0
-0.05
-0.1
1-Jan-97
1-Feb-97
1-Mar-97
1-Apr-97
1-May-97
1-Jun-97
1-Jul-97
1-Aug-97
1-Sep-97
1-Oct-97
1-Nov-97
1-Dec-97

Stochastic seasonality

As the figures show, the pattern of seasonality is similar in each year. However, the are some year-specific differences in the seasonality component.

We use econometric models that are able to identify this *stochastic seasonality* for the entire sample period.

Literature

Harvey (2013, Chapter 3.6, *Cambridge University Press*)

Harvey and Luati (2014, *J Am Stat Assoc*):

Suggest the *dynamic Student's-t location model* that includes both stochastic local level and stochastic seasonality components.

Volatility is assumed to be constant for this model.

The authors focus on modelling the conditional mean (or location) of the dependent variable.

Literature

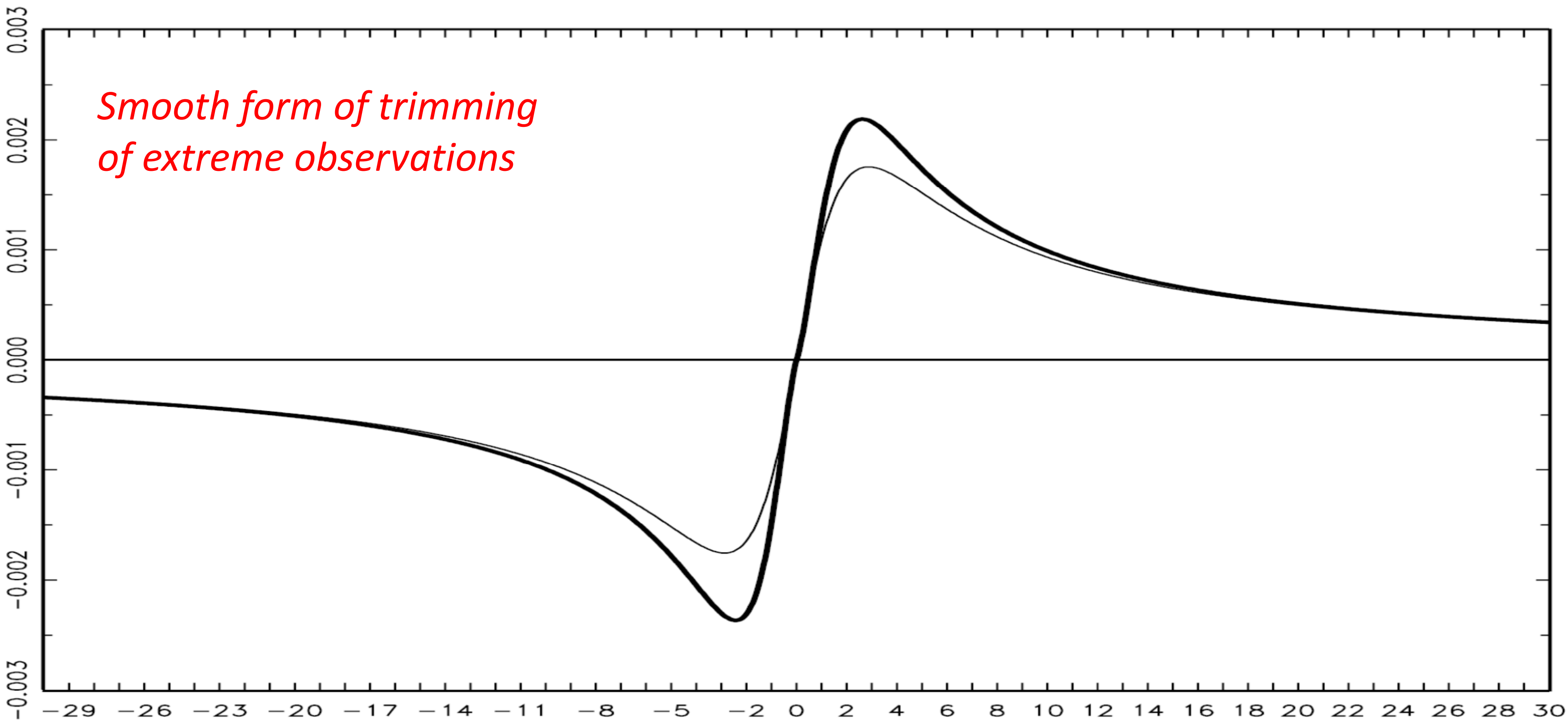
The dynamic Student's-t location model belongs to the family of *Dynamic Conditional Score (DCS)* models (Harvey 2013, C*ambridge University Press*).

A property of all DCS models is that extreme observations are discounted when they enter the dynamic equations of the model.

Hence, DCS are robust the extreme values and may provide better estimates of conditional mean and conditional volatility of the dependent variable.

The next figures show how the score function (updating term) depends on the error term (epsilon) that represents the arrival of new information:

Fig. 4(a) $u_{\mu,t}$ for t-DCS (thin) and Skew-Gen-t-DCS (thick)



Literature

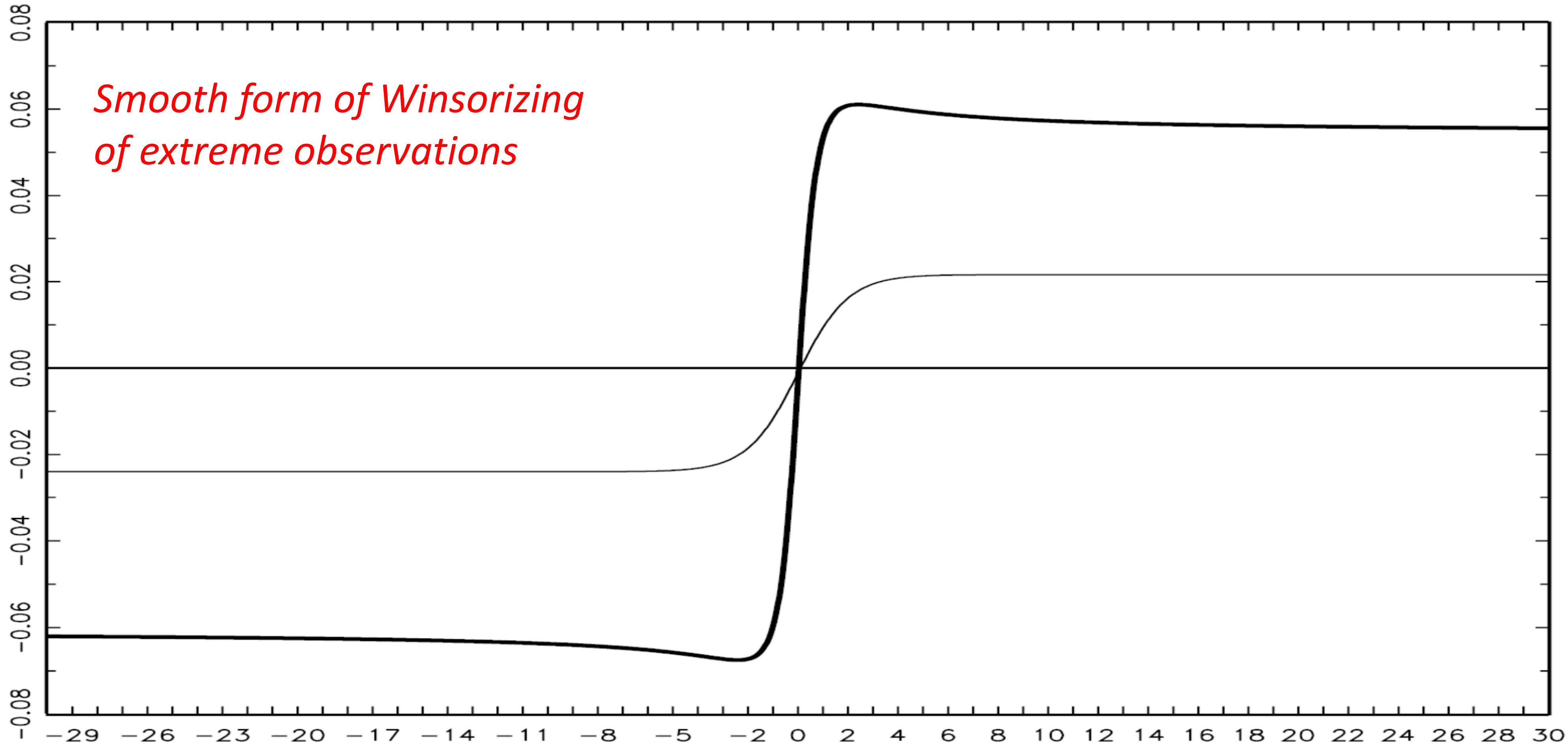
Caivano, Harvey and Luati (2016, SERIEs) suggest the *dynamic EGB2 location model*, which also includes stochastic local level and stochastic seasonality components.

EGB2 (Exponential Generalized Beta distribution of the second kind)

Volatility is assumed to be constant for this model.

The authors focus on modelling the conditional mean (or location) of the dependent variable.

Fig. 4(b) $u_{\mu,t}$ for EGB2-DCS (thin) and NIG-DCS (thick)



Literature

As the figures show, the dynamic t and EGB2 location models transform differently the arriving new information.

Caivano, Harvey and Luati (2016) find that the performance of those models depend on the dataset.

Contributions of the present paper

In the present work, we estimate the dynamic t and EGB2 location models for GTQ/USD data and study their performance.

We also suggest two new dynamic location models: (i) dynamic Skew-Gen-t location model; (ii) dynamic Normal-Inverse Gaussian (NIG) location model.

We consider time-varying volatility for the irregular term:

Beta-t-EGARCH

Fig. 4(a) $u_{\mu,t}$ for t-DCS (thin) and Skew-Gen-t-DCS (thick)

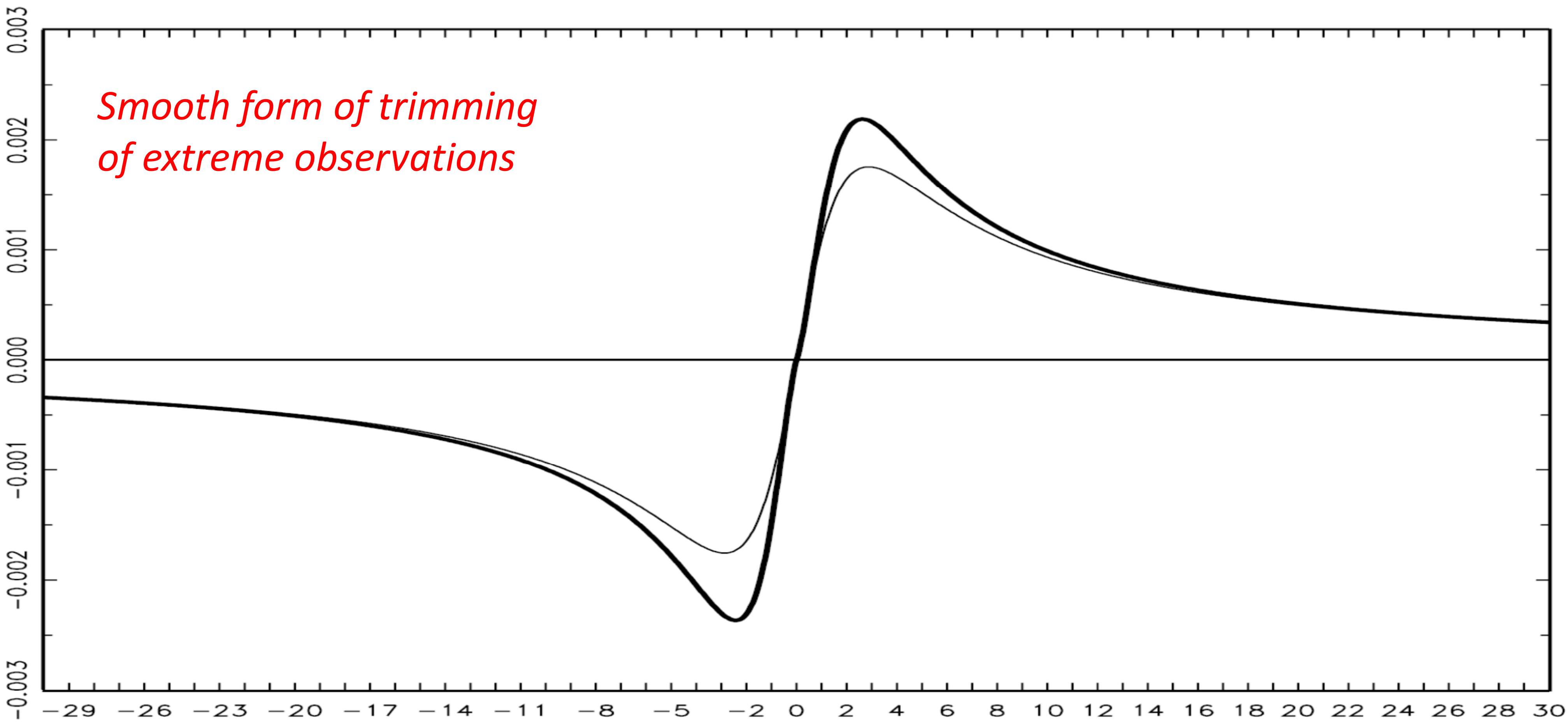


Fig. 4(c) $u_{\lambda,t}$ for t-DCS (thin) and Skew-Gen-t-DCS (thick)

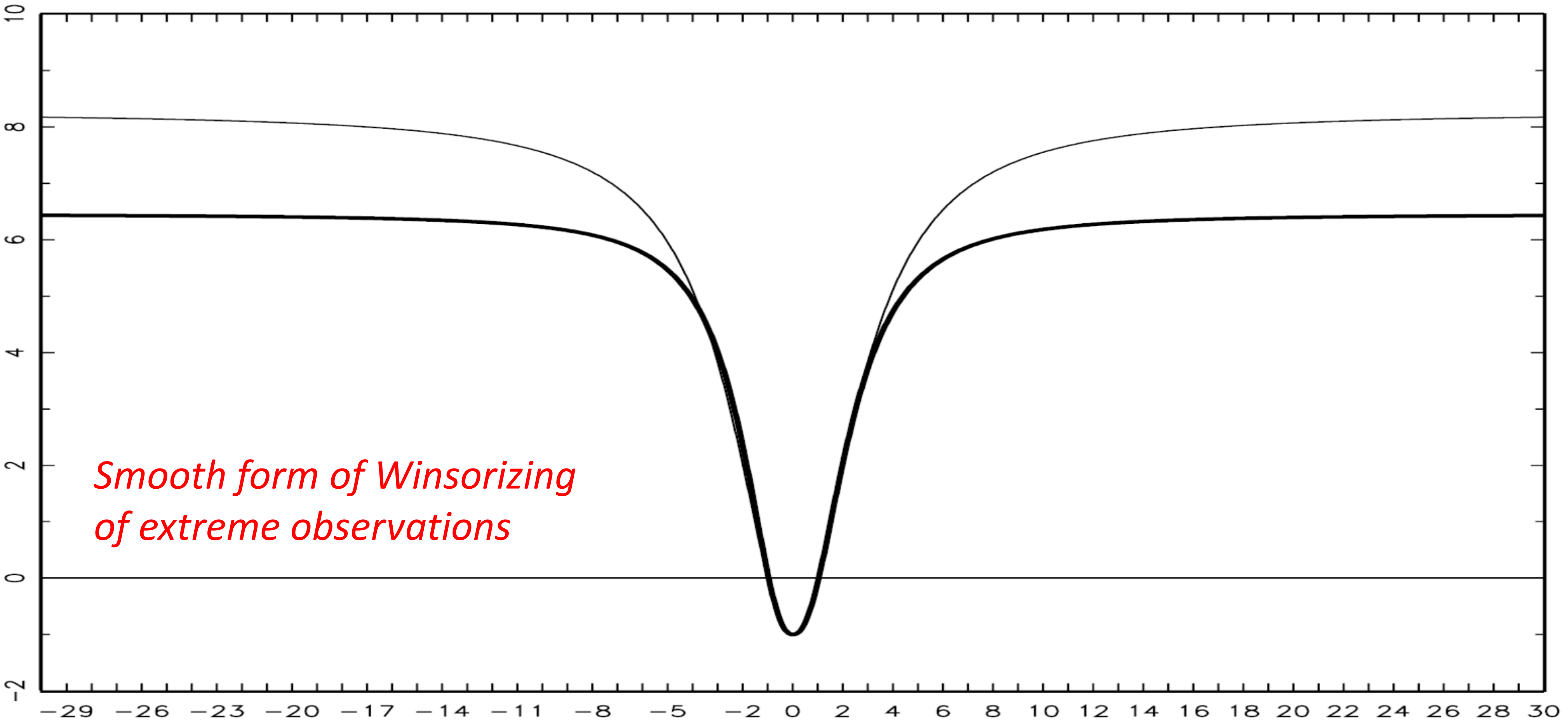


Fig. 4(b) $u_{\mu,t}$ for EGB2-DCS (thin) and NIG-DCS (thick)

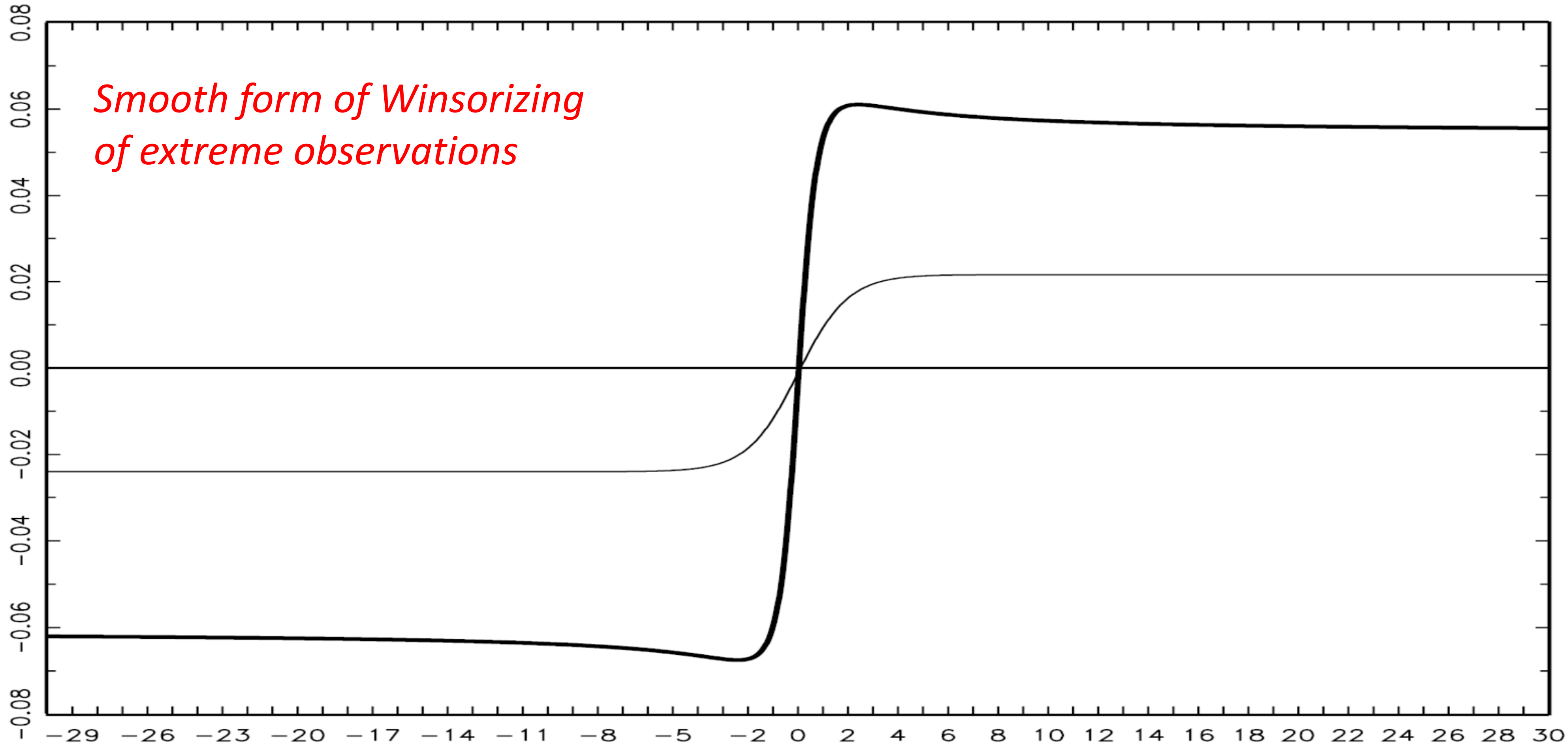
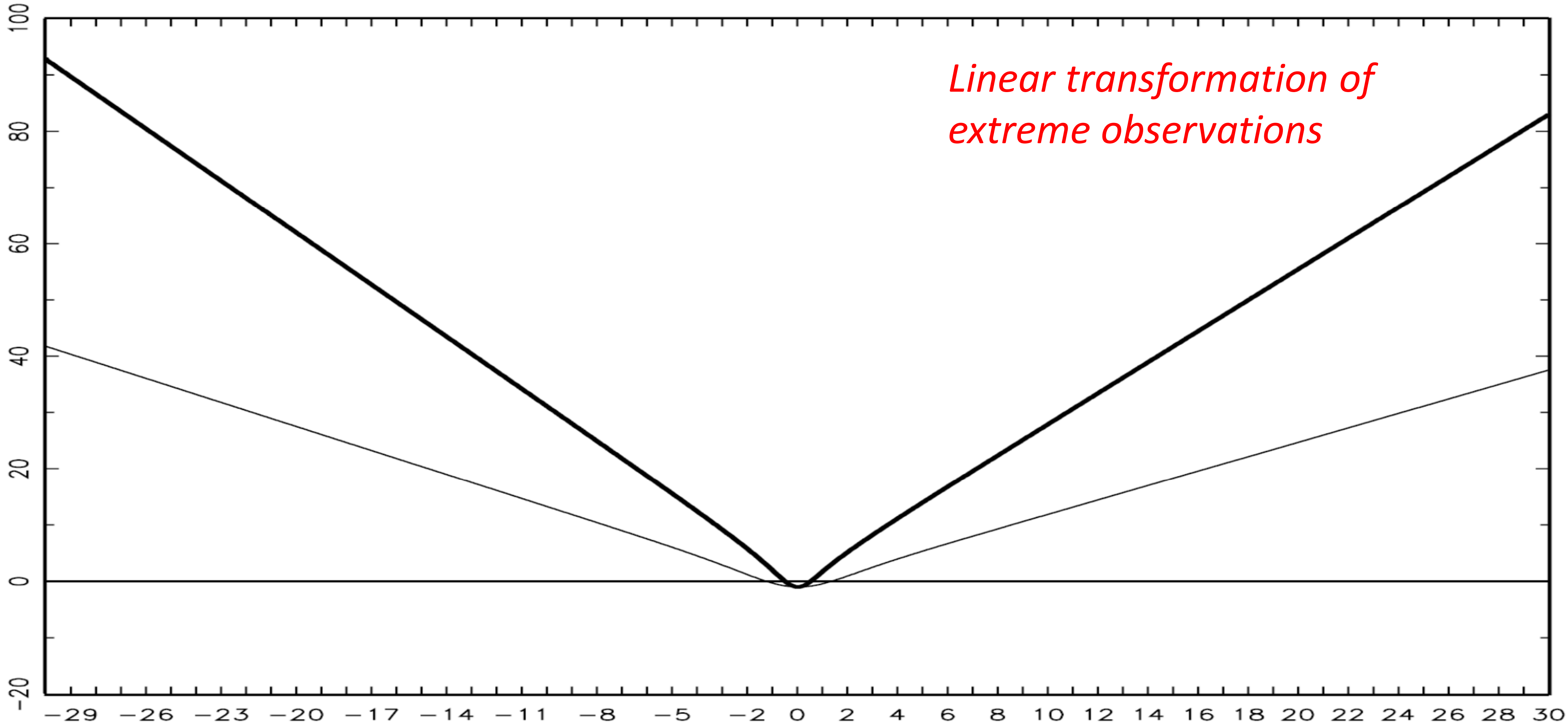


Fig. 4(d) $u_{\lambda,t}$ for EGB2-DCS (thin) and NIG-DCS (thick)



Econometric formulation

The GTQ/USD rate for day t, p_t, is modelled as:

$$p_t = \mu_t + s_t + v_t = \mu_t + s_t + \exp(\lambda_t)\epsilon_t$$

where μ_t is the *local level component*

s_t is the *stochastic seasonal component*

v_t is the *irregular component* (with time-varying volatility driven by λ_t)

ε_t is the *standardized error term* with alternative distributions.

Specifications of the error term

(i) $\varepsilon_t \sim t[0,1,\exp(\nu)+2]$ i.i.d. (Student's t-distribution) →

dynamic Student's-t location model

Symmetric probability distribution

ν influences the tail-heaviness of the distribution

Specifications of the error term

(ii) $\varepsilon_t \sim \mathrm{Skew-Gen}-t[0{,}1, \tanh(\tau)\exp(\nu)+2, \exp(\eta)]$ i.i.d. (Skewed generalized t-distribution) →

dynamic Skew-Gen-t location model (NEW)

Asymmetric probability distribution

τ influences asymmetry of the distribution

ν influences tail heaviness of the distribution

η influences peakedness in the center of the distribution

Specifications of the error term

(iii) $\varepsilon_t \sim EGB2[0,1,\exp(\xi),\exp(\zeta)]$ i.i.d. (EGB2 distribution) →

dynamic EGB2 location model

Asymmetric probability distribution

ξ and ζ influence both tail-heaviness and asymmetry of the distribution

Specifications of the error term

(iv) $\varepsilon_t \sim NIG[0,1,\exp(\nu),\exp(\nu)\tanh(\eta)]$ i.i.d. (NIG distribution)
→ *dynamic NIG location model (NEW)*

Asymmetric probability distribution

ν influences the tail-heaviness of the distribution

η influences the asymmetry of the distribution

Local level and stochastic seasonal

Local level:

$$\mu_t = \mu_{t-1} + \delta u_{\mu,t}$$

I(1) model updated by the score function with respect to location

We motivate this by performing the Augmented Dickey-Fuller (1979) (ADF) unit root test for GTQ/USD time series. The unit root null hypothesis is not rejected.

δ is a time-constant parameter to be estimated.

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ADF statistic, constant plus trend	−0.8073(0.9637)	NA	November	7.4298
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Local level and stochastic seasonal

Stochastic seasonal:

$$s_t = D_t' \rho_t = (D_{\mathrm{Jan},t}, D_{\mathrm{Feb},t}, \ldots, D_{\mathrm{Dec},t})' \rho_t$$

$$\rho_t = \rho_{t-1} + \gamma_t u_{\mu,t}$$

Each element of the 12x1 vector ρ_t is defined as:

$$\gamma_{jt} = \gamma_j \text{ for } D_{jt} = 1 \text{ and } \gamma_{jt} = -\gamma_j/(12-1) \text{ for } D_{jt} = 0$$

where $\gamma_1, \ldots, \gamma_{12}$ are time-constant parameters to be estimated.

Time-varying volatility of the irregular component

Beta-t-EGARCH(1,1):

$$\lambda_t = \omega + \beta\lambda_{t-1} + \alpha u_{\lambda,t-1}$$

ω, α, β are time-constant parameters to be estimated.

We also estimated an extended version of Beta-t-EGARCH(1,1):

Beta-t-EGARCH(1,1) with leverage effects.

However, the leverage effect parameter was not significant.

t-DCS		Skew-Gen-t-DCS		EGB2-DCS		NIG-DCS	
δ	11.6767*** (0.2957)	δ	9.6840*** (0.2568)	δ	0.9985*** (0.0116)	δ	0.3326*** (0.0105)
γ_{Jan}	−1.0548*** (0.0734)	γ_{Jan}	−0.8595*** (0.0578)	γ_{Jan}	−0.0835*** (0.0051)	γ_{Jan}	−0.0279*** (0.0020)
γ_{Feb}	0.4225*** (0.0341)	γ_{Feb}	0.3582*** (0.0284)	γ_{Feb}	0.0361*** (0.0031)	γ_{Feb}	0.0119*** (0.0011)
γ_{Mar}	−0.6163*** (0.0295)	γ_{Mar}	−0.5109*** (0.0242)	γ_{Mar}	−0.0525*** (0.0028)	γ_{Mar}	−0.0176*** (0.0011)
γ_{Apr}	−0.3205*** (0.0903)	γ_{Apr}	−0.3008*** (0.0741)	γ_{Apr}	−0.0156* (0.0092)	γ_{Apr}	−0.0051* (0.0030)
γ_{May}	0.8895*** (0.0639)	γ_{May}	0.7650*** (0.0549)	γ_{May}	0.0736*** (0.0052)	γ_{May}	0.0242*** (0.0019)
γ_{Jun}	1.1123*** (0.0656)	γ_{Jun}	0.8921*** (0.0494)	γ_{Jun}	0.0982*** (0.0057)	γ_{Jun}	0.0326*** (0.0022)
γ_{Jul}	3.2336*** (0.1538)	γ_{Jul}	2.8908*** (0.1377)	γ_{Jul}	0.2633*** (0.0114)	γ_{Jul}	0.0868*** (0.0045)
γ_{Aug}	1.3050*** (0.0493)	γ_{Aug}	1.0514*** (0.0383)	γ_{Aug}	0.1137*** (0.0035)	γ_{Aug}	0.0378*** (0.0016)
γ_{Sep}	1.2205*** (0.1380)	γ_{Sep}	0.9919*** (0.1059)	γ_{Sep}	0.1131*** (0.0113)	γ_{Sep}	0.0372*** (0.0038)
γ_{Oct}	−0.2428*** (0.0483)	γ_{Oct}	−0.2224*** (0.0382)	γ_{Oct}	−0.0191*** (0.0044)	γ_{Oct}	−0.0067*** (0.0015)
γ_{Nov}	−0.6171*** (0.0494)	γ_{Nov}	−0.5120*** (0.0387)	γ_{Nov}	−0.0562*** (0.0041)	γ_{Nov}	−0.0182*** (0.0015)
γ_{Dec}	4.0804*** (0.1674)	γ_{Dec}	3.4212*** (0.1369)	γ_{Dec}	0.3637*** (0.0108)	γ_{Dec}	0.1215*** (0.0044)
ω	−0.9301*** (0.0484)	ω	−1.0078*** (0.0495)	ω	−0.8338*** (0.0438)	ω	−0.6769*** (0.0368)
β	0.7976*** (0.0102)	β	0.7800*** (0.0105)	β	0.8281*** (0.0089)	β	0.8273*** (0.0092)
α	0.2004*** (0.0064)	α	0.2229*** (0.0068)	α	0.1298*** (0.0043)	α	0.1385*** (0.0046)
λ_0	−2.9936*** (0.8533)	λ_0	−2.9098*** (0.8859)	λ_0	−3.4120*** (0.5187)	λ_0	−2.4672*** (0.5576)
ν	1.8338*** (0.0368)	τ	0.0387*** (0.0084)	ξ	0.3544*** (0.0370)	ν	1.0697*** (0.0349)
		ν	1.4936*** (0.0451)	ζ	0.2505*** (0.0404)	η	0.0559*** (0.0125)
		η	0.8207*** (0.0117)				
C_λ	0.3642	C_λ	0.3318	C_λ	0.4791	C_λ	0.4674
LL	3.1134	LL	**3.1211**	LL	3.0922	LL	3.0925
AIC	−6.2209	AIC	**−6.2356**	AIC	−6.1783	AIC	−6.1788
BIC	−6.2011	BIC	**−6.2137**	BIC	−6.1574	BIC	−6.1580
HQC	−6.2140	HQC	**−6.2280**	HQC	−6.1710	HQC	−6.1716
LR	0.0077*** (0.0021)	LR	NA		0.0288*** (0.0067)	LR	0.0285*** (0.0060)

Results on model performance

The likelihood-based metrics show that:

(i) *Skew-Gen-t-DCS is superior to t-DCS*

(ii) *NIG-DCS is superior to EGB2-DCS*

Thus, for GTQ/USD data, the new DCS location models of our paper are more parsimonious than the previous models from the body of literature.

(iii) *Skew-Gen-t is superior to NIG-DCS*

Results on stochastic annual seasonality

For all models, the following figures show that the importance of the stochastic annual seasonality component has reduced in the past years:

Fig. 2(a) Annual seasonality s_t for t-DCS

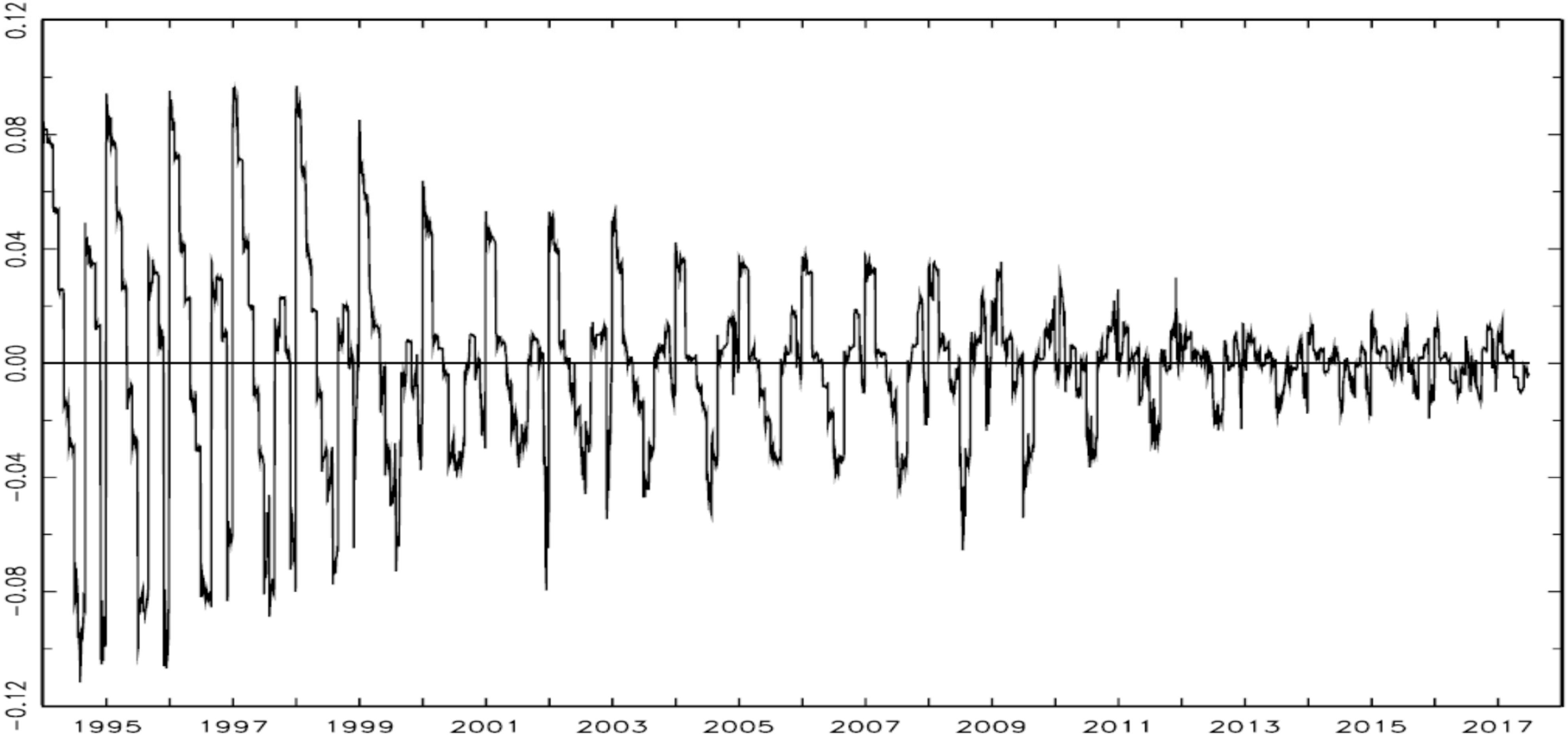


Fig. 2(b) Annual seasonality s_t for Skew-Gen-t-DCS

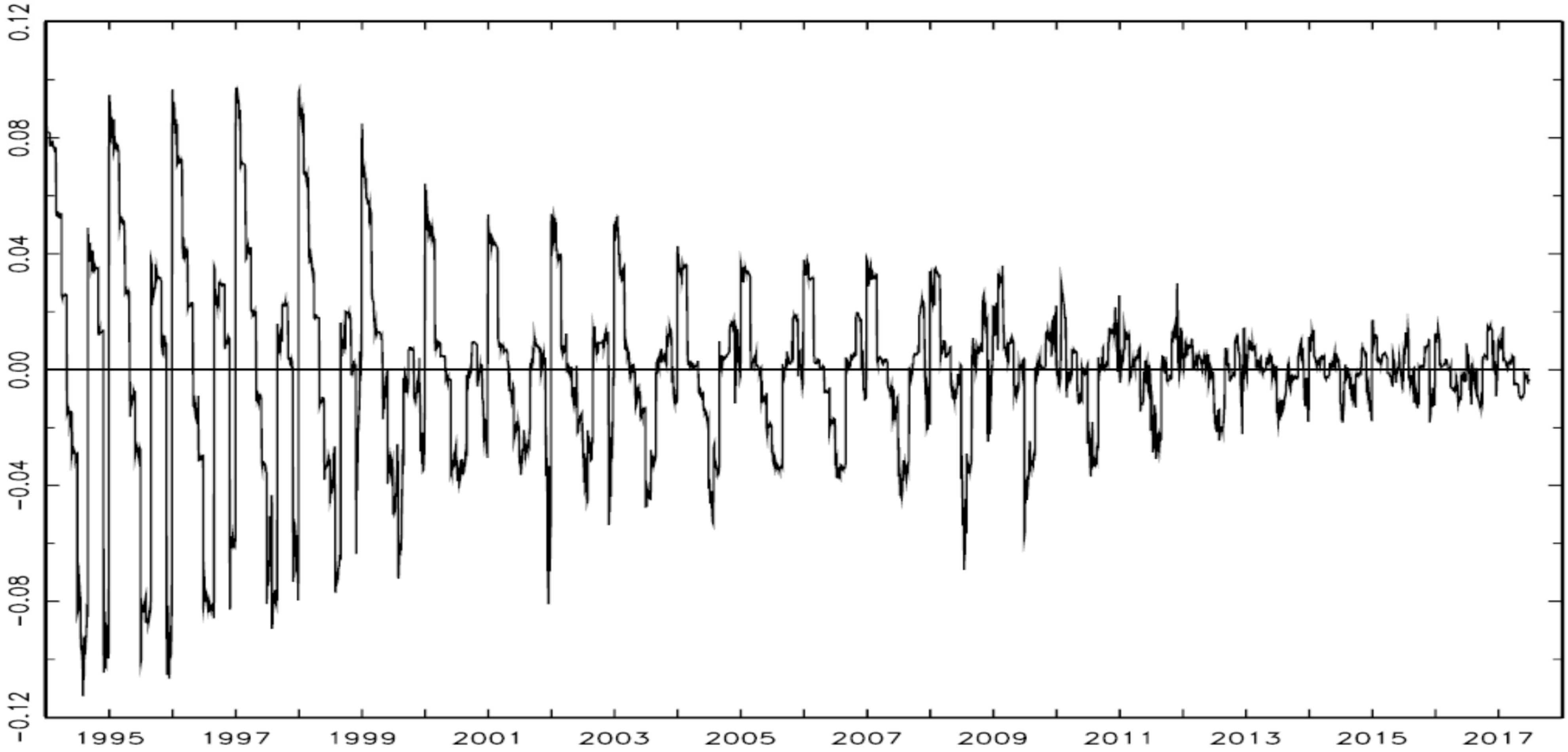


Fig. 2(c) Annual seasonality s_t for EGB2-DCS

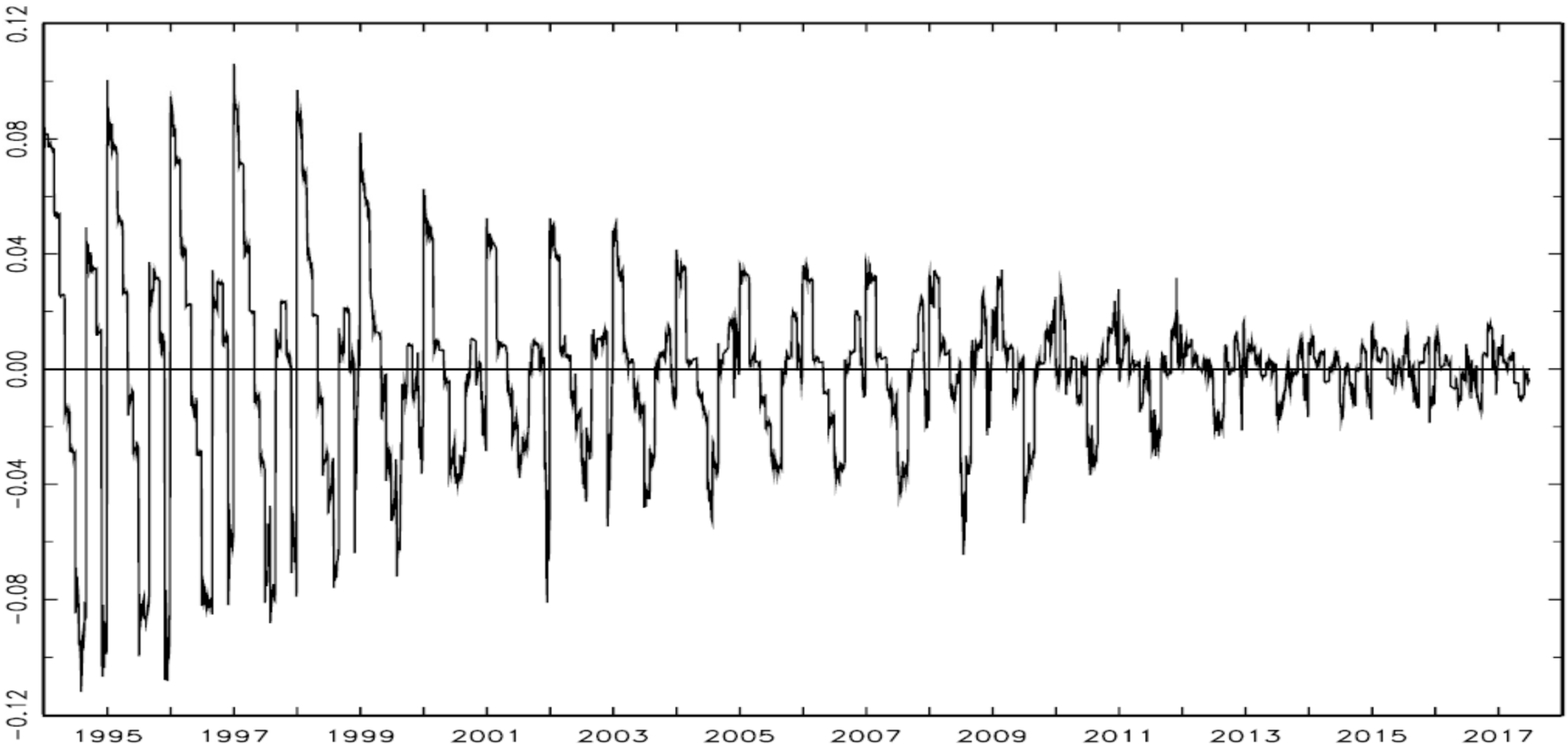
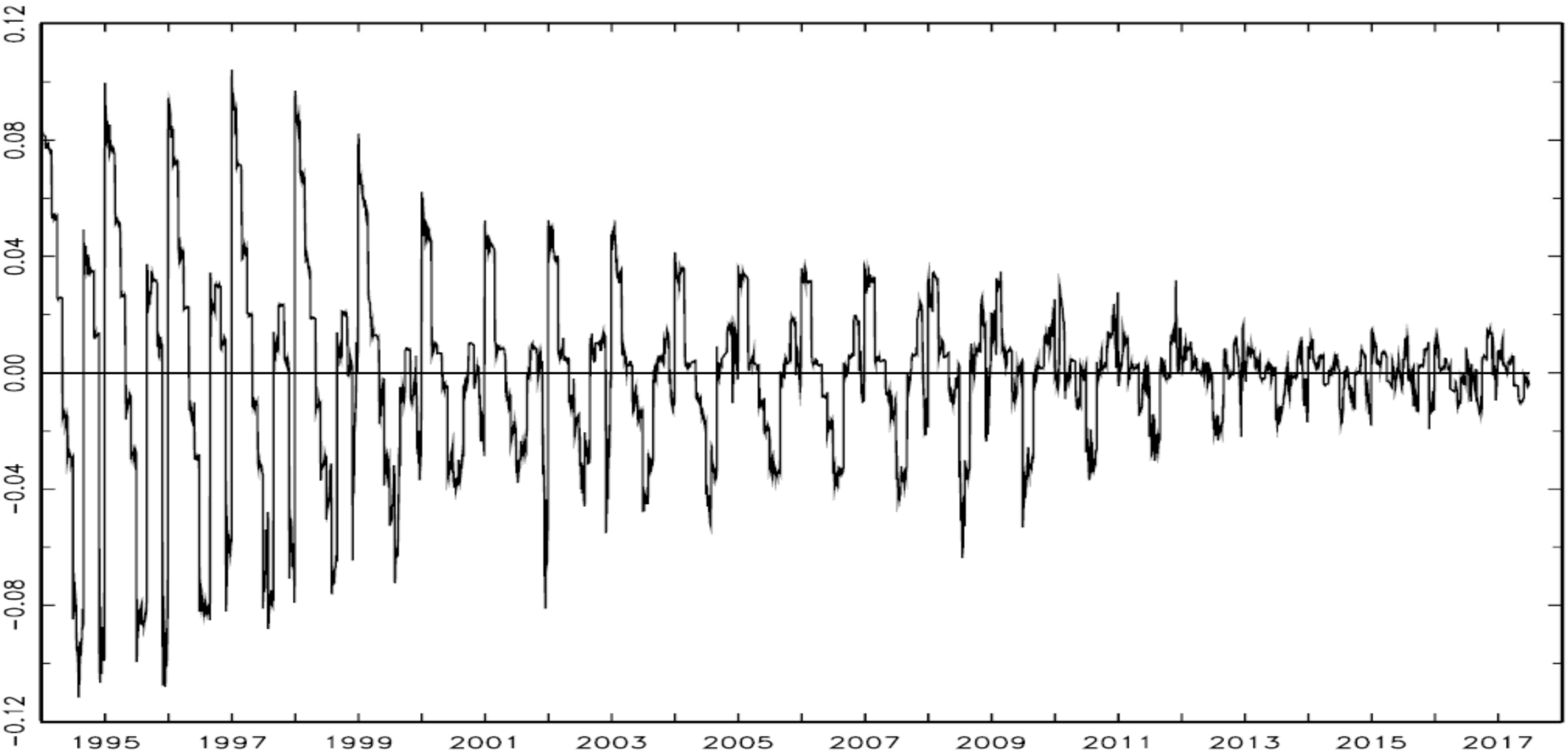


Fig. 2(d) Annual seasonality s_t for NIG-DCS



Reasons for decreasing importance of annual seasonality effects

(i) Reduction of total exports growth rate

(ii) Reduction in the relative importance of the total exports

(iii) Reduction of agricultural product exports compared to total exports

Year	Regime	Exports	Exports %	Exports mean %	Imports	Imports %	Imports mean %
1993		1,249,135.00			1,825,336.80		
1994	R1	1,719,461.80	37.7%		2,416,061.50	32.4%	
1995	R1	2,314,620.36	34.6%		2,855,612.18	18.2%	
1996	R1	2,356,943.45	1.8%		2,581,500.20	−9.6%	
1997	R1	3,147,110.12	33.5%		3,551,071.23	37.6%	
1998	R1	3,502,412.56	11.3%		4,288,290.71	20.8%	
1999	R1	2,663,945.10	−23.9%		3,361,987.53	−21.6%	
2000	R1	2,954,127.01	10.9%	R1: 15.1%	3,406,576.45	1.3%	R1: 11.3%
2001	R2	2,496,071.04	−15.5%		3,595,573.30	5.5%	
2002	R2	2,218,061.44	−11.1%		3,845,055.97	6.9%	
2003	R2	2,661,740.70	20.0%		4,305,029.40	12.0%	
2004	R2	3,074,419.20	15.5%		4,588,573.70	6.6%	
2005	R2	3,644,831.80	18.6%		6,010,208.40	31.0%	
2006	R2	3,813,656.50	4.6%		7,279,563.30	21.1%	
2007	R2	4,219,396.20	10.6%		9,363,544.70	28.6%	
2008	R2	5,034,553.30	19.3%	R2: 7.8%	11,695,311.00	24.9%	R2: 17.1%
2009	R3	4,795,305.10	−4.8%		9,362,202.80	−19.9%	
2010	R3	5,490,744.44	14.5%		11,169,889.52	19.3%	
2011	R3	6,576,115.10	19.8%		13,451,267.10	20.4%	
2012	R3	6,561,021.10	−0.2%		13,767,708.70	2.4%	
2013	R3	6,464,898.00	−1.5%		13,791,808.10	0.2%	
2014	R3	6,640,461.10	2.7%		14,239,560.90	3.2%	
2015	R3	6,409,639.40	−3.5%		14,058,324.00	−1.3%	
2016	R3	6,421,918.00	0.2%	R3: 3.4%	13,924,693.80	−1.0%	R3: 2.9%

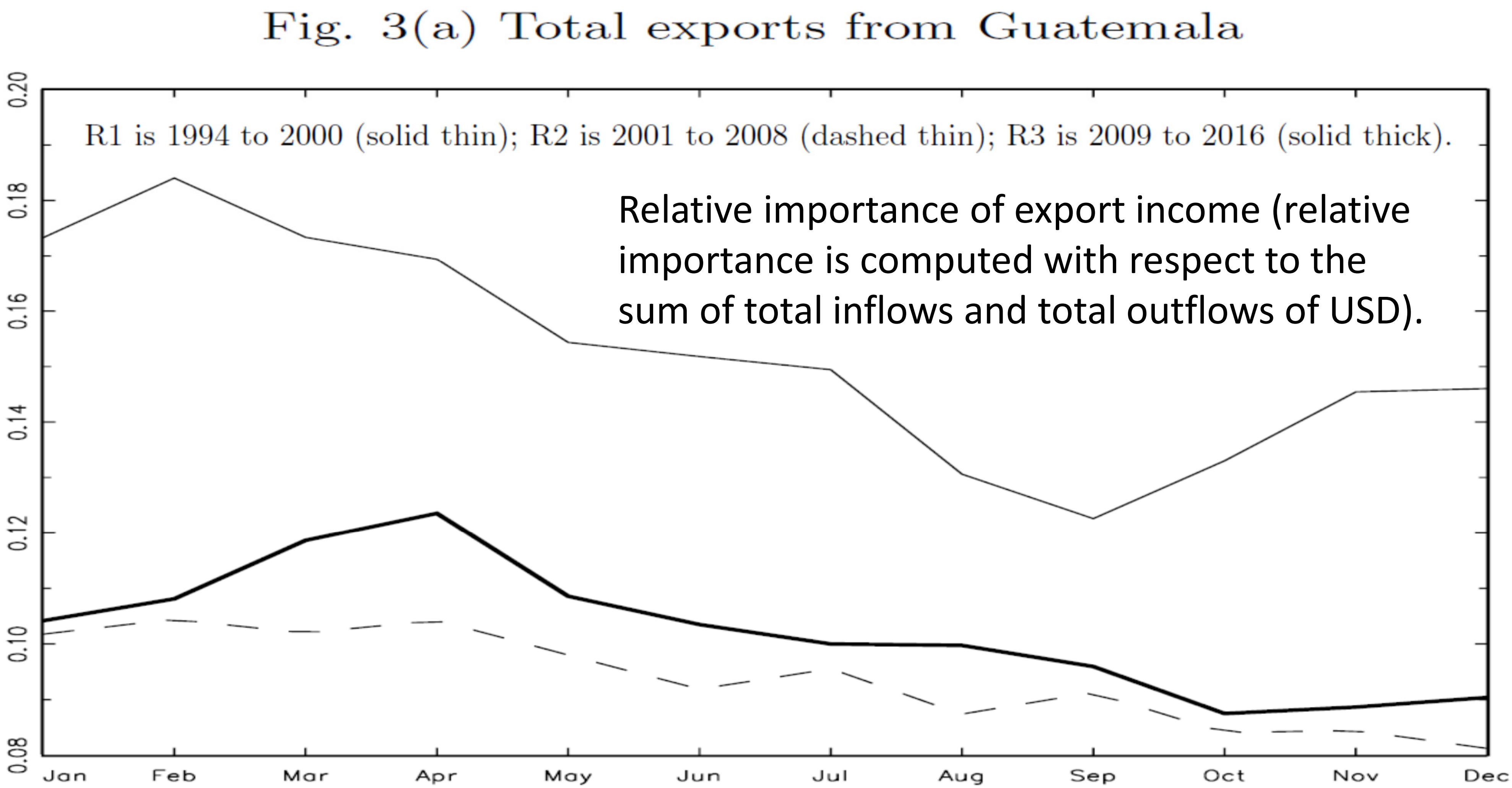


Fig. 3(a) Total exports from Guatemala
R1 is 1994 to 2000 (solid thin); R2 is 2001 to 2008 (dashed thin); R3 is 2009 to 2016 (solid thick).
Relative importance of export income (relative importance is computed with respect to the sum of total inflows and total outflows of USD).
0.20
0.18
0.16
0.14
0.12
0.10
0.08
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Year	Total exports	Coffee	Sugar	Banana	Cardamom	Other products	CSBC (%)	Other (%)
1994	1,502.60	318.3	161.5	113.9	42.3	866.6	42.33%	57.67%
1995	1,935.50	539.3	238.2	138.6	40.7	978.7	49.43%	50.57%
1996	2,030.70	472.4	202.1	155.2	39.4	1,161.60	42.80%	57.20%
1997	2,344.10	589.5	255.4	151.1	38	1,310.10	44.11%	55.89%
1998	2,581.70	586.6	316.7	191.4	36.7	1,450.30	43.82%	56.18%
1999	2,460.40	562.6	195.2	135.4	56.5	1,510.70	38.60%	61.40%
2000	2,699.00	575	190.8	167.5	79.4	1,686.30	37.52%	62.48%
2001	2,411.70	306.5	212.6	185	96.1	1,611.50	33.18%	66.82%
2002	4,162.10	261.8	227	216.3	93.3	3,363.70	19.18%	80.82%
2003	4,459.40	299.4	212.3	210	78.9	3,658.80	17.95%	82.05%
2004	5,033.60	328	188	229.7	73.8	4,214.10	16.28%	83.72%
2005	5,380.90	464.1	236.6	238.1	70.4	4,371.70	18.76%	81.24%
2006	6,012.80	464	298.6	216.8	83.4	4,950.00	17.68%	82.32%
2007	6,897.70	577.3	358.1	300.2	137.1	5,525.00	19.90%	80.10%
2008	7,737.40	646.2	378.1	317.1	208	6,188.00	20.02%	79.98%
2009	7,213.70	582.3	507.7	414.8	304.1	5,404.80	25.08%	74.92%
2010	8,462.50	713.9	726.7	353.3	308.1	6,360.50	24.84%	75.16%
2011	10,400.90	1,174.20	648.8	475.3	296.9	7,805.70	24.95%	75.05%
2012	9,978.70	958.1	803	499.8	250.3	7,467.50	25.17%	74.83%
2013	10,024.80	714.5	941.9	594.7	215.6	7,558.10	24.61%	75.39%
2014	10,803.50	668.2	951.7	651.8	239.8	8,292.00	23.25%	76.75%
2015	10,674.80	663	850.8	715.1	243	8,202.90	23.16%	76.84%
2016	10,449.40	649.1	816.7	702.6	229	8,052.00	22.94%	77.06%

Thank you for your attention!

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