การพรรณนาพฤติกรรมการเคลื่อนไหวอัตราผลตอบแทนส่วนเกินของพันธบัตรรัฐบาลประเทศไทย โดยใช้แบบจำลอง STAR

โดย

อรุณศรี แซ่ฉั่ง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
เศรษฐศาสตรมหาบัณฑิต

คณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์

พ.ศ. 2549

STAR

Time varying excess returns on Thai Government Bond: A STAR Model

Miss Arunsri Saechung

. . 2549

ISBN 974-9729-45-5

STAR

31 . . 2549

(.)

(. .)

(.)

(. .)

Vector STAR (Smooth Transition Autoregression)

Vector STAR

16 . . 2542 30 . . 2547

(Regime switching behavior)

. .   . .

. .   .

(   )

. . 2549

สารบาญ

สารบาญตาราง

สารบาญภาพประกอบ

1

1.1

1.1 . . 2547
16 . . 2536 1.1
. . 2547
5 . . 2536

Wei (2541)

(Stock Index) (2542)[1]

---

[1] . ( ) . ( )

2

(2546)

7

1.1

. . 2536-2547

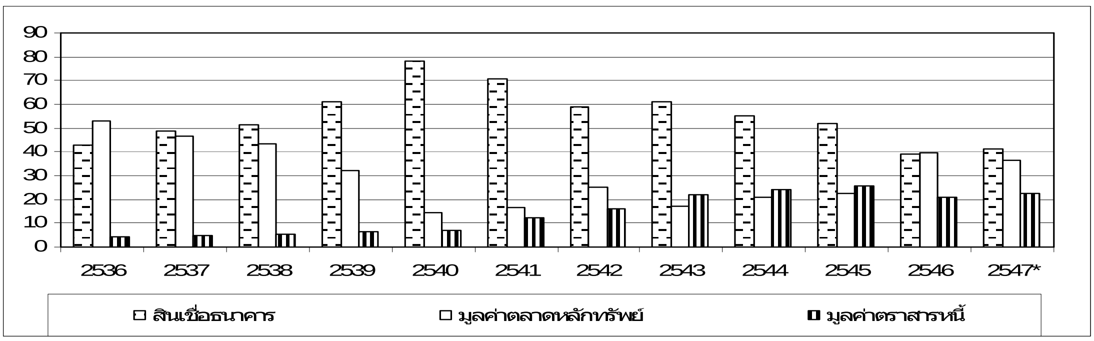
:

	(Government Bond)	(T –bill)	(State Enterprise Bond)	(BOT/FIDF/PLMO Bonds)	(Corporate Bond)	
2536	-	-	60.4	-	21.1	81.5
2537	-	-	57.1	-	59.8	116.9
2538	-	-	55.2	29.5	47.5	132.2
2539	-	-	57.4	138.8	36.2	232.4
2540	-	-	49.3	191.5	40.9	281.7
2541	400.0	-	46.7	55.0	37.8	539.5
2542	333.7	77.0	95.3	-	289.3	795.3
2543	94.1	240.9	111.7	-	151.2	597.9
2544	149.2	441.4	57.6	112.0	106.7	866.9
2545	471.5	519.0	47.5	-	98.9	1,136.9
2546	107.5	368.99	56.4	219.5	181.3	930.6
2547	271.3	569.0	88.47	317.3	122.4	1,368.5

: (Thaibdc)

1.1

. . 2536-2547



: 2547

: . . 2547

(risk-free rate)[2] 1
(repurchase rate)
2

Stationary Litterman and Scheinkman
(1991)
1 (repurchase rate)

5 1 2 5 7 10

10

2 (risk premium)

2

1

Fama (1984) (forward interest rate)

(spot rate) . .1990

Fama Contemporaneous Correlation[3]

Campbell and Shiller (1988) Campbell (1991)

Variance - Covariance

(Simultaneous-equation Model)

Campbell and Ammer (1993) (Asset pricing framework) VAR (Vector Autoregression Model)[4]

Campbell and Ammer

VAR Adjust R^2

VAR Adjust R^2

---

[3] Contemporaneous Correlation

[4] VAR(p) Vector AR(p) (Autoregresiive)

(Time series)

. . 1999 Ball and Torous

Stochastic Volatility (SVOL) Engle
(1982) Bollerslev (1986) ARCH/GARCH (Autoregressive Conditional Heteroscedasticity/ Generalized Autoregressive Conditional Heteroscedasticity)

ARCH GARCH
(Structural breaks) Lamoureux and Lastrapes (1990)
Hamilton(1989) [5] (parameters)
Ang and Bekaert (1998) (business cycle)
(real rates) (expected inflation)
Markov regime-switching
( )
Markov regime-switching Cai (1994) Gray (1996)
regime-switching ARCH
regime-switching GARCH

Markov-switching
regime regime
Markov-switching

5

Dueker and Sola (2004)
Markov regime-switching Vector STAR
(Smooth Transition Autoregression)
Vector STAR Teräsvirta and Anderson (1992)
VAR
Vector STAR

regime regime Vector STAR
Markov-Switching Vector STAR
Markov-Switching
Vector STAR regime
determination
regime (TAR) regime
Markov-Switching (state variable)
State
Vector STAR
regime
regime 2 regimes
regime regime switching
Vector STAR
Clements and Smith (2001)
Vector STAR
Taylor, Van Dijk and Franess (2000)
Lekkos and Milas (2004) Vector STAR

Vector STAR

Vector STAR

(risk factors forecasting variables)

2

2

1.2 ________________

1. Vector STAR

2.

2 (1) (Slope of Term Structure Interest Rate) (2) (Stock Return)

1.3 _____________

1.

1 [6]

---

[6] 1 repurchase rate (risk free rate) 1

(risk premium)

2. 5 1 2 5 7 10

3.
Vector STAR
(sufficient degree of freedom)
asymptotic
properties
5 16 . . 2542
30 . . 2547 1,300

1.4 _________

1. Unit Root Test

Stationary

2. VAR
Vector STAR
VAR Vector STAR

3. Linearity Test

VAR

4. Vector STAR

Maximum Likelihood Estimation (MLE)

5. regime 1 regime 2
Vector STAR
regime 1 regime 2
Vector STAR
VAR
6.
Vector STAR In Sample Out of Sample
(Robustness Check) Vector STAR
VAR In Sample Out
of Sample Vector STAR
Vector STAR
Out of Sample Vector STAR

1.5

1. Government Bond Yield

2. 1
repurchase rate
3.

1.6 ______________________

1.

2.

2

2

(Theory of Demand Asset Portfolio Choice) 2

(1)

(2)

STAR

2.1

2.1.1 (Theory of Asset Demand Theory of Portfolio Choice)[1]

1. (Wealth)

2. (Expected Return)

3. (Risk)

[1] Mishkin, 1992

4. (Liquidity)

(Loanable

Funds Framework)

2.1.1.1 (Loanable Funds Framework)

(Demand Curve: D^B)

(Supply Curve: S^B)

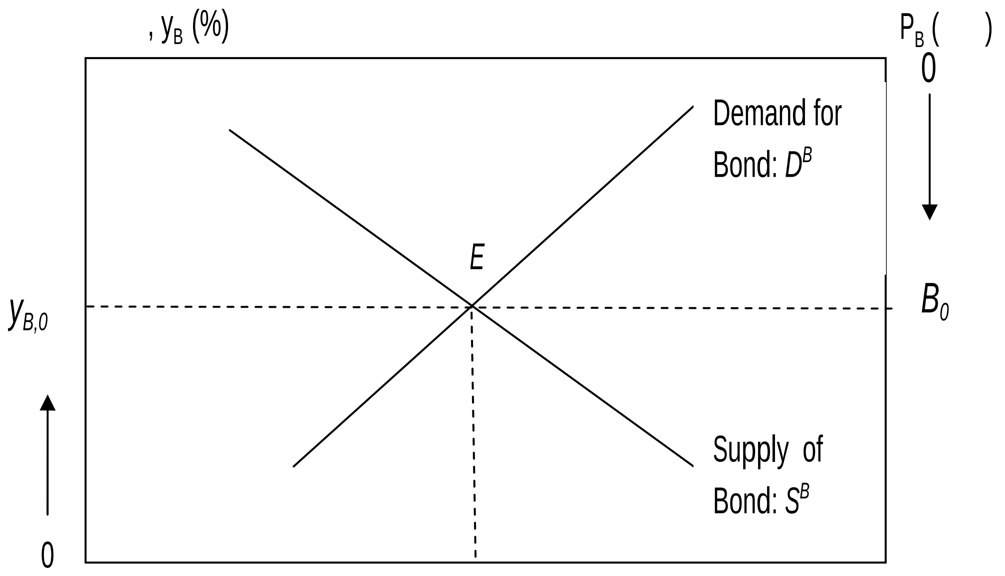
(Demand for Bond: D^B)

(Supply of Bond: S^B) 2.1

2.1

E

2.1



. (Excess Demand)

$y_{B,o}$ B_0

. (Excess Supply)

$y_{B,o}$ B_0

(The Theory of Assets Demand)

(1) (Wealth)

(Wealth)

(Shift)

(2)
(Expected Return on Bonds Relative to Alternative Assets)

(Shift)

(Shift)

(3) (Riskness of
Bonds Relative to Alternative Assets)

(Shift)

(4) (Liquidity of
Bonds Relative to Alternative Assets)

(Shift)

(Shift)

2.2 (2.1)

$$r_B = f\left(\overset{+}{Wealth},\ \overset{+}{E(r_i)},\ \overset{-}{Risk},\ \overset{+}{Liquidity}\right) \tag{2.1}$$

r_B =

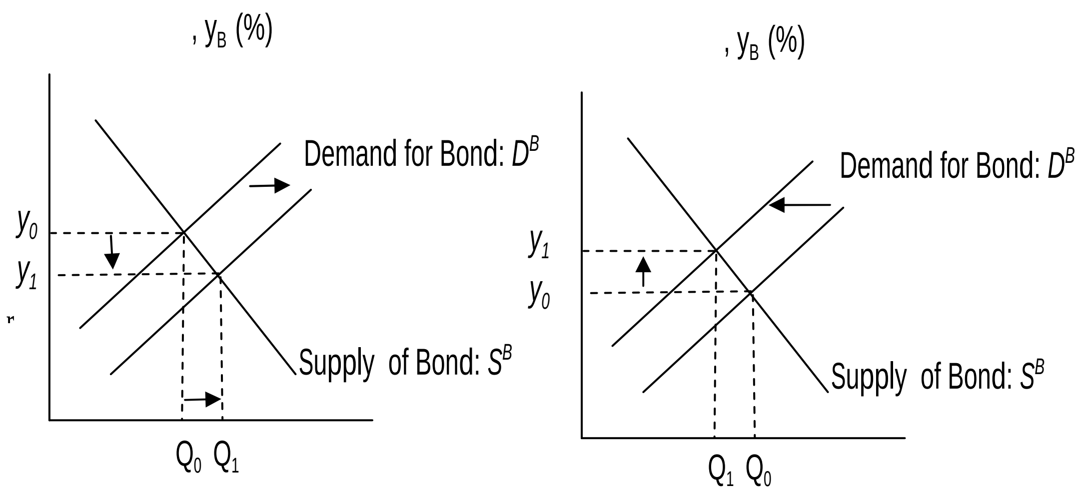
Wealth =

$E(r_i)$ =

Risk =

Liquidity =

2.2



2.2

2.2.1

Campbell and Ammer (1993) Evans and Lewis (1994)

(Real

Interest Rate) (Inflation Rate)

(Real Economic Activity)

Estrella and Hardouvelis (1991)

(Economic Expansion)

(Economic Recession) Estrella and

Mishkin (1997) Davis, Henry and Pesaran (1994)

Fama (1990a) Campbell and Shiller (1991) Evans and Lewis (1994)

. . 1996

Elton, Gruber and Mei

Boudoukh (1994) . . 2003 Lekkos and Milas

STAR

2 5 7 10

Keim and Stambugh (1986)

. . 1928 . . 1978

(2.2)

$$\left(LTGOV - y_{TB}\right)_t = \alpha_0 + \alpha_1\left(-\log\left(SP_{t-1} / \overline{SP}_{t-1}\right)\right)_t + \varepsilon_t \quad (2.2)$$

$LTGOV$ =

y_{TB} = 1

$LTGOV - y_{TB}$ =

"term premium"

SP_{t-1} = Standard and Poor's Composite *t-1*

$\overline{SP}_{t-1}$ = Standard and Poor's Composite

t-1 45

(2.2) α_1

Keim and Stambugh

(2.3)

$$\left(LTGOV_i - y_{TB}\right)_t = \alpha_0 + \alpha_1\left(-\log\left(SP_{t-1} / \overline{SP}_{t-1}\right)\right)_t + \varepsilon_t \quad (2.3)$$

$LTGOV_i$ =

i

y_{TB} = 1

$LTGOV - y_{TB}$ =

"term premium"

SP_{t-1} = Standard and Poor's Composite

t-1

$\overline{SP}_{t-1}$ = Standard and Poor's Composite

t-1 45

Keim and Stambugh (Portfolio) 10

6

6

6 – 12

240 α_1 (2.3)

6 2

Chen, Roll and Ross (1983)

(low-grade bonds) Fama and French (1989), (1993) Shiller (1992)

(Portfolio of Corporate Bond)

(Common Risk Factors)

. . 1996 Kwan

. . 1986 . . 1990

t-1

t

t-1

t

(2541)

1

(2542)

(2542)

.( ) .

( ) . . 2537 . . 2541

Cointegration Engle and Granger Ordinary Least Square (OLS)

(2.4) (2.5)

$$RSONE = f(RMLR,\ RMS,\ RQ,\ RSET,\ RMCS,\ RINF) \quad (2.4)$$

$$RTFB = f(RMLR,\ RMS,\ RQ,\ RSET,\ RMCS,\ RINF) \quad (2.5)$$

RSONE = . ( )

RTFB = . ( )

RMLR =

RMS =

RQ =

RSET =

RMCS =

RINF =

(2.4) (2.5)

1 Basis Point

36-51 Basis Point 78-83 Basis Point

43

Khanthavit (1994) Constantinides (1992) CIR

X

. . 2517 . . 2535

1 3 6 12 Khanthavit

(2.6)

$$y(n,t) = -0.0246 + \frac{1}{n}\left[0.5\ln(H(n)) - H^{-1}(n)\{X_t - 0.3882\exp(0.0363n)\}^2 + \{X_t - 0.3882\}^2 \right] \quad (2.6)$$

$y(n,t)$ = n t

$H(n)$ = n $(H(n) = 0.0854 + 0.9146(0.0726n))$

X_t =

(2.6)

Khanthavit

2.2.2 STAR

STAR

3

Smooth Transition Autoregression (STAR)

Granger and Teräsvirta (1992) Markov-Switching

Teräsvirta and Anderson (1992) STAR Mean Square Prediction Error (MSPE) STAR MSPE (Linear Model) Sarantis (1999) STAR

Morkov-Switching Kilian and Taylor (2003) STAR

Teräsvirta, Dijk and Mederiros (2003) 3 Linear Autoregression STAR Neural network LSTAR 47 G7

Bårdan, Hurn and Mchugh (2003) Dijk, Franses and Teräsvirta (2000) LSTAR

(Asymmetric)

Kräger and Kugler (1993) Self-Exciting Threshold Autoregression (SETAR)

. . 1980-1990

Clements and Smith (2001)

Lekkos and Milas (2004)

Vector STAR

2 5 7 10

(Discount Bonds)

. . 1976 . . 2000 Vector STAR (Smooth Transition Autoregression)

(2.7)

$$y\_i_t = \mu_1 + \sum_{j=1}^{p} \beta_{1,j} y\_i_{t-j} \left(1 - G(s_t)\right) + \mu_2 + \sum_{j=1}^{p} \beta_{2,j} y\_i_{t-j} \left(G(s_t)\right) + \varepsilon_t \qquad (2.7)$$

y_i_t = (k x 1)

i i = 2 5 7 10

μ_1, μ_2 = (k x 1)

$\beta_{1,j}, \beta_{2,j}$ = (k x k)

ε_t = (k x 1) iid

$G(s_t)$ = (Transition Function);

0 1

s_t = (Transition Variable)

t

(Transition Function; $G(s_t)$)

$$G(s_t;\gamma,C) = \frac{1}{1+\exp\left(\frac{-\gamma(s_t-C)}{\sigma_{s_t}}\right)} \quad ; \ \gamma>0 \tag{2.8}$$

$$G(s_t;\gamma,C_1,C_2) = \frac{1}{1+\exp\left(\frac{-\gamma(s_t-C_1)(s_t-C_2)}{\sigma_{s_t}}\right)} \quad ; \ C_1 \leq C_2 \ , \ \gamma>0 \tag{2.9}$$

Lekkos and Milas Vector STAR

VAR

(error variance) Vector STAR

Logistic

. . 2005

Pérez-Rodrígues, Torra and Félix Stock

Index STAR Artificial Neural

Network (ANN) out-of sample Pérez-Rodrígues, Torra and Félix

ANN out-of sample

STAR

3

Smooth Transition Autoregressive (STAR) Model

3 2
Vector Smooth Transition Autoregressive (Vector STAR) Model

2
Vector STAR Teräsvirta (1993, 1994) Eitrheim and Teräsvirta (1996)

3.1 Vector Smooth Transition Autoregressive (STAR) Model

/

Brenner Harjes and Kroner (1996) Ball and Torous (1999) Stochastic Volatility (SVOL) GARCH GARCH Koedjik (1997) Anderson and Lund (1997) Ball and Torous (1999) . . 1990 Lamoureux and Lastrapes (Structural breaks)

GARCH Lamoureux and Lastrapes Hamilton and Susmel (1994) Cai (1994) So, Lam and Li (1998) Markov switching . . 1998 Naik and Lee

regime switching
GARCH
Ang and Bekaert (1998) regime switching
out-of sample
single regime . . 2001 Bekaert, Hodrick and Marshall
(term premium) regime switching 2 regimes
(peso problems) . . 2003 Evans regime
switching 3 regime good fit

regime switching Teräsvirta and
Anderson (1992) Smooth Transition Autoregression (STAR)
regime switching Markov
switching STAR
regime
Markov switching

regime
regime
Smooth Transition Autoregressive Model (STAR)
regime STAR
2 (1) regime (regime
)
regimes STAR
regime regime
2 (Van Dijk, 1999) (2) regime

(Autocorrelation)
(Autoregression (AR(p)) AR(p)

(single equation)

(Greene, 378)

Contemporaneous correlation)[1]

Vector

Autoregression (VAR) VAR

1

Vector STAR

STAR VAR Lekkos and

Milas (2004) Lekkos and Milas Vector

STAR

Vector STAR

VAR (3.1) Vector STAR

p

$$\mathbf{Y_t} = \left(\boldsymbol{\mu}^1 + \sum_{j=1}^{P} \boldsymbol{\beta}_j^1 \mathbf{Y}_{t-j}\right)\left(1 - G\left(s_t;\gamma,c\right)\right) + \left(\boldsymbol{\mu}^2 + \sum_{j=1}^{P} \boldsymbol{\beta}_j^2 \mathbf{Y}_{t-j}\right)\left(G\left(s_t;\gamma,c\right)\right) + \boldsymbol{\varepsilon}_t \qquad (3.1)$$

$\mathbf{Y_t}$ = $\left(y_{1t}\ x_{1t}\ x_{2t}\ \ldots\ldots\ldots\ x_{mt}\right)'$

m t ; t = 1, 2, ..., T

$\boldsymbol{\mu}^i$ = $\left(\mu_1^i\ \mu_2^i\ \ldots\ldots\ldots\ \mu_m^i\right)'$

(Intercept) regime i; i = 1, 2

$\boldsymbol{\beta}^i$ =

$$\begin{matrix} \beta_{11}^i & \beta_{12}^i & ? & \beta_{1m}^1 \\ \beta_{21}^i & \beta_{22}^i & ? & \beta_{2m}^1 \\ @ & @ & B & @ \\ \beta_{m1}^i & \beta_{m2}^i & ? & \beta_{mm}^i \end{matrix}$$

---

[1] Contemporaneous correlation Cross section data Seemingly Unrelated Regression(SUR)

regime i ; i = 1, 2

β^{i}_{jk} $\mathbf{Y_{k,t-j}}$ regime i

$\mathbf{Y_{kt}}$

$\boldsymbol{\varepsilon_t}$ = $(\varepsilon_{1t}\ \varepsilon_{2t}\ \ldots\ldots\ldots\ \varepsilon_{mt})'$

iid

$\mathbf{E(\varepsilon_t) = 0}\ ;\forall t$ $\mathbf{Var(\varepsilon_t) = \sigma^2 I_m}\ ;\forall t \neq 0$

$\mathbf{G(s_t;\gamma,c)}$ = (Transition Function);

0 1

Vector STAR

t

$\mathbf{(s_t)}$

$\mathbf{s_t}$ = (Transition Variable) [2]

t

$s_t = (y_{t-d})\ ;d > 0$ [3]

$S_t = (z_t)$

$\boldsymbol{\gamma}$ = $\boldsymbol{\gamma}$

regime regime

$\mathbf{c}$ =

2

(Threshold between to Two Regimes)

---

[2] (Transition Variable)

Markov regime-switching

[3] Self-Exciting TAR Model Kräger and Kugler (1993) Self-Exciting TAR (SETAR) Model

. . 1980 . . 1990

(3.1) Vector STAR

VAR

VAR Vector STAR 2

1 2

$G(s_t;\gamma,c)$ $G(s_t;\gamma,c)$ 0 1

$G(s_t;\gamma,c)$ regime 2

$G(s_t;\gamma,c)$

0 1 Vector STAR VAR

$G(s_t;\gamma,c)$ 0 1

Vector STAR Switch 1

2 Vector TAR

$G(s_t;\gamma,c)$

Vector STAR $G(s_t;\gamma,c)$

Vector STAR (s_t)

$G(s_t;\gamma,c)$ 2

Logistic Exponential

(1) Logistic (3.2) Vector

STAR Logistic LSTAR

$$G(S_t;\gamma,C) = \frac{1}{1+\exp\left(\frac{-\gamma(S_t - C)}{\sigma_{S_t}}\right)} \quad ; \quad \gamma > 0 \qquad (3.2)$$

σ_{S_t} =

(3.2) Logistic

$G(S_t;\gamma,C)$ (S_t)

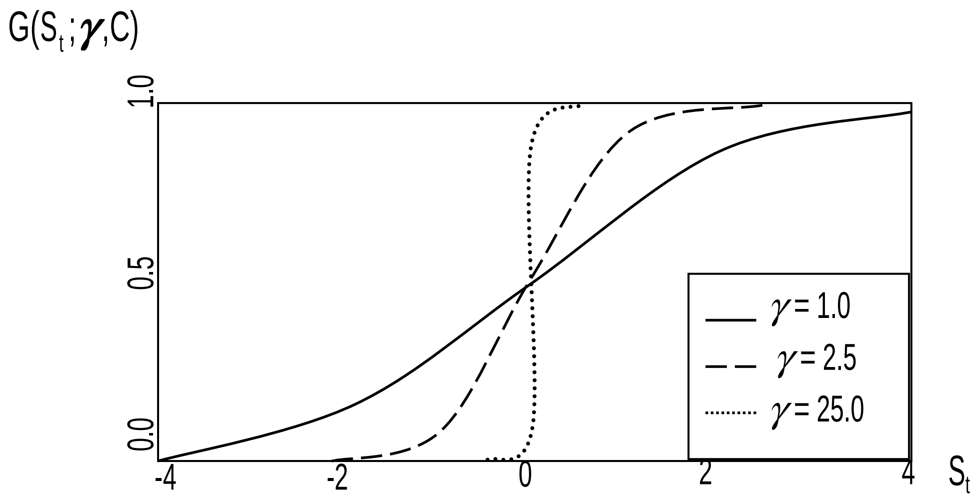
$(S_t >,C)$ $(S_t < C)$ asymmetric

γ (infinity)

$\gamma = 0$ $G(S_t;\gamma,C) = \frac{1}{2}$

LSTAR γ
$(\gamma \rightarrow \infty)$ regimes
regime LSTAR
TAR (Two-Regime Threshold Autoregressive Model) 3.1
Logistic C (Threshold)
γ

3.1
Logistic Function



3.1 $\gamma \rightarrow \infty$ Logistic
(Indicator Function)[4] $\lim_{\gamma \to \infty} G(S_t;\gamma,C) = I[S_t > C]$
Van Dijk, Teräsvirta and Franses (2000)
LSTAR
(asymmetric business cycle) 3.1
LSTAR
(growth rate of an output) $S_t = Y_{t-d}$ $C \approx 0$ $Y_{t-d} >$
0 LSTAR regimes
$Y_{t-d} < 0$ LSTAR regimes
LSTAR

[4] $I[A]=1$; A $I[A]=0$;

LSTAR

Anderson and Teräsvirta (1992) Teräsvirta, Tjøstheim and Granger (1994)

(industry production index)

OECD . . 2003 Holmes and Maghrebi LSTAR

. . 1977 . . 2000

(2) Exponential (3.3) Vector STAR Exponential ESTAR

$$G(S_t;\gamma,C) = 1 - \exp\left(\frac{-\gamma(S_t - C)^2}{\sigma_{S_t}}\right) \quad ; \gamma > 0 \qquad (3.3)$$

(asymmetric business cycle)

(deviation) Purchasing Power Parity (PPP) (symmetric business cycle) Teräsvirta (1994) Exponential (3.3) 3.2 Michael, Nobay and Peel (1997) Baum, Caglayan and Barkoulas (1998) ESTAR γ Exponential ((3.3)) $\gamma = 0$ $\gamma \to \infty$ Exponential ESTAR Model 3.2 Jansen and Teräsvirta (1996) Exponential Function Quadratic Logistic Function Quadratic Logistic Function (3.4) 3.3

$$G(S_t;\gamma,C_1,C_2) = \frac{1}{1+\exp\left(\frac{-\gamma(S_t-C_1)(S_t-C_2)}{\sigma_{S_t}}\right)} \quad ; c_1 \leq c_2,\ \gamma>0 \qquad (3.4)$$

(3.4) Quadratic Logistic

Logistic $\gamma = 0$ $\gamma \to \infty$

$G(S_t;\gamma,C_1,C_2)$ 1 $S_t < C_1$ $S_t > C_2$ $G(S_t;\gamma,C_1,C_2)$

0 $C_1 < S_t < C_2$ Quadratic Logistic

$G(S_t;\gamma,C_1,C_2)$

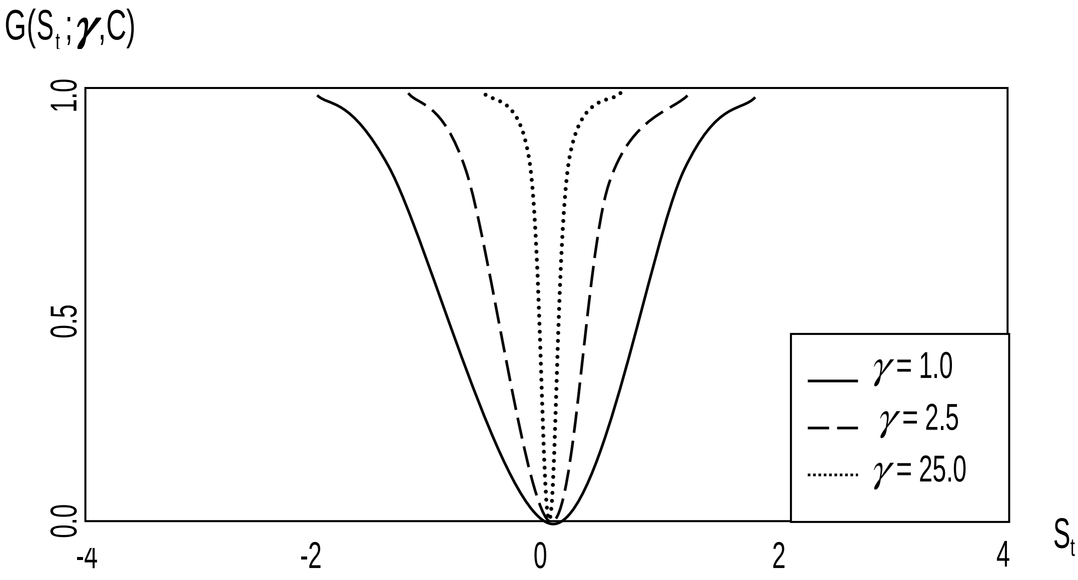
(S_t) (S_t)

$(C = 0)$ (S_t)

(C_1,C_2)

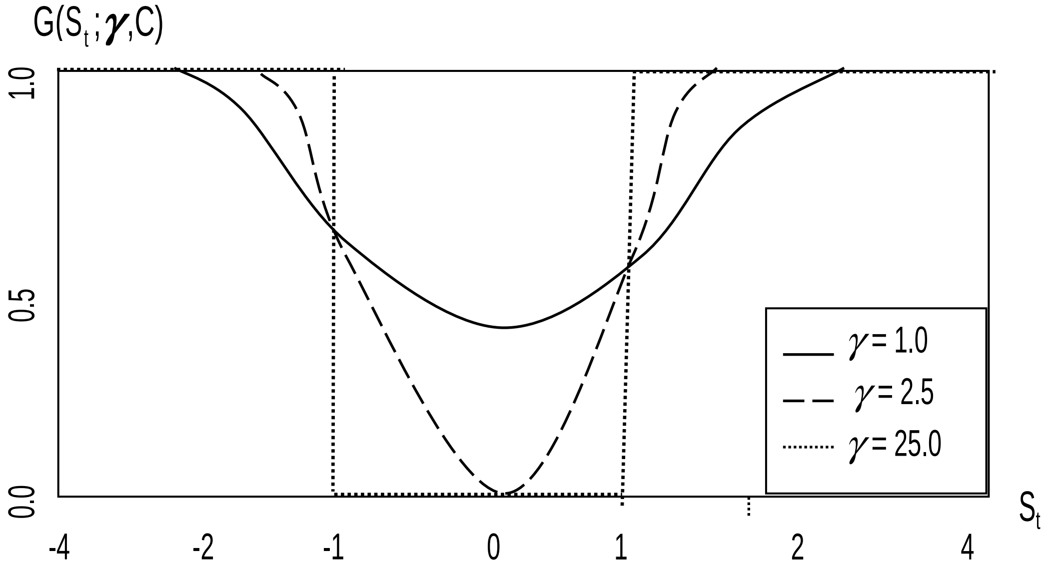
3.2

Exponential Function (C = 0)



3.3

Quadratic Logistic Function $(C_1 = -1, C_2 = 1,)$



Van Dijk, Teräsvirta and Franses (2000)

ESTAR

3.3 regime

S_t C_1 C_2 S_t C_1

C_2 $S_t < C_1$ $S_t > C_2$ regimes S_t

C $S_t < C_1$ $S_t > C_2$

regime ESTAR

Kapetanios, Shin and Snell (2003)

Clements and Smith (2001)

. . 1977 . . 2000 Holmes and

Maghrebi (2003)

3.2 Vector STAR

2

Vector STAR (3.1)

Logistic ((3.2)) Quadratic Logistic (

(3.4))

Vector

STAR

3.2.1 Vector STAR

Vector Autoregression

(VAR Model) VAR 2

VAR

Vector STAR VAR

(Initial Values) Vector STAR Numerical

search

Vector STAR

Vector STAR

$\gamma = 0$ $G(S_t; \gamma, C) = \frac{1}{2}$ t

Vector STAR regimes

VAR Teräsvirta (1994)

3 (Taylor Series Approximation)[5]

$G(S_t; \gamma, C)$ $\gamma = 0$ (3.1)

---

[5] f(x) n $x_0 = 0$

$$f(x) \approx f_n(x) = f(x_0) + \frac{df(x_0)}{dx}(x - x_0) + \frac{1}{2!}\frac{d^2 f(x_0)}{dx}(x - x_0)^2 + \dots\dots\dots + \frac{1}{n!}\frac{d^n f(x_0)}{dx}(x - x_0)^n$$

cross product

(3.5)

$$\mathbf{Y_t} = \boldsymbol{\alpha}_t + \sum_{j=1}^{P} \boldsymbol{\Gamma}_j^0 \mathbf{z}_{t-j}^0 + \sum_{j=1}^{P} \boldsymbol{\Gamma}_j^1 \mathbf{z}_{t-j}^1 + \sum_{j=1}^{P} \boldsymbol{\Gamma}_j^2 \mathbf{z}_{t-j}^2 + \sum_{j=1}^{P} \boldsymbol{\Gamma}_j^3 \mathbf{z}_{t-j}^3 + \boldsymbol{\varepsilon}_t \qquad (3.5)$$

$\mathbf{Y_t}$ = $(y_{1t}\ x_{1t}\ x_{2t}\ \ldots\ldots\ldots\ x_{mt})'$

$\boldsymbol{\alpha}_t$ = $(\alpha_{1t}\ \alpha_{1t}\ \alpha_{2t}\ \ldots\ldots\ldots\ \alpha_{mt})'$

(Intercept)

$$\boldsymbol{\Gamma}_j^i = \begin{matrix} \tau_{11}^i & \tau_{12}^i & ? & \tau_{1m}^i \\ \tau_{21}^i & \tau_{22}^i & ? & \tau_{2m}^i \\ @ & @ & B & @ \\ \tau_{m1}^i & \tau_{m2}^i & ? & \tau_{mm}^i \end{matrix}$$

cross product τ_{jk}^i $\mathbf{z}_{k,t-j}^i$

$\mathbf{z}_{t-j}^i$ = $(y_{1t-j}s_{t-j}^i\ \ y_{2t-j}s_{t-j}^i\ \ldots\ldots\ldots\ y_{mt-j}s_{t-j}^i)'$

$\boldsymbol{\varepsilon}_t$ = $(e_{1t}\ e_{2t}\ \ldots\ldots\ldots\ e_{mt})'$

iid

(3.5)

(Linear in Parameters)

(3.5)

$\boldsymbol{\Gamma}_j^1, \boldsymbol{\Gamma}_j^2, \boldsymbol{\Gamma}_j^3$ 0

Wald Test

$H_{01}:\ \boldsymbol{\Gamma}^1 = \boldsymbol{\Gamma}^2 = \boldsymbol{\Gamma}^3 = 0$

$H_{11}:\ \boldsymbol{\Gamma}^i \neq 0$ i

Teräsvirta (1994)
(Linearity: against STAR Model) (S_t)

S_t p-value
Van Dijk and Franses (2000), Van Dijk (2002)
Lekkos and Milas (2004) STAR

$G(S_t;\gamma,C)$
2 Logistic
(3.2) Quadratic Logistic (3.4)
Teräsvirta (1994) Sequence of Nested Test
Logistic 3
$\gamma = 0$ $G(S_t;\gamma,C_t)$ Vector STAR
((3.1)) LSTAR (3.5)
Quadratic Logistic
(3.5) LSTAR ESTAR
Sequence of Nested Test

$H_{04}:\Gamma^3 = 0$

$H_{03}:\Gamma^2 = 0 \mid \Gamma^3 = 0$

$H_{02}:\Gamma^1 = 0 \mid \Gamma^2 = \Gamma^3 = 0$

p-value H_{03} Quadratic Logistic
p-value H_{03} Logistic
(
.)
Van Dijk, Teräsvirta and Franses (2000) Korhonen (2001) Jorge, Salvador and Julián (2005)

STAR Maximum Likelihood Estimation

4

4 2 1 2

4.1 ______________________

(System of Equations)

Fama (1990) Contemporaneous Correlation Fama Campbell and Shiller (1988) Campbell (1991)

(4.1)

Vector STAR

$$\mathbf{Y_t} = \mu^1 + \sum_{j=1}^{P} \beta_j^1 \mathbf{Y_{t-j}} \left(1 - G\left(s_t;\gamma,c\right)\right) + \mu^2 + \sum_{j=1}^{P} \beta_j^2 \mathbf{Y_{t-j}} \left(G\left(s_t;\gamma,c\right)\right) + \varepsilon_t \quad (4.1)$$

$\mathbf{Y_t}$ = $\left(exre\_iy_T \ \ slope_T \ \ exrre\_set_T\right)'_{3x1}$

$exre\_iy_t$ =

i : i = 1, 2, 5, 7 10

$slope_t$ =

$exre\_set_t$ =

(4.1) 3 (1)
(Excess Bond Return) (2)
(Slope of Term Structure Interest Rate) (3)
(Excess Stock Return) 3

(4.1)
(1) i
(Excess Bond Return) $exre\_iy_t$ (4.2)

$$exre\_iy_T = r_{iy,t} - r_{f,t}$$

$$r_{iy,t} = \ln \frac{B_{i,t}}{B_{i,t-1}} \qquad (4.2)$$

$$B_{iy,t} = \exp\left\{-\text{spot rate}_{iy,t} * y\right\}$$

$exre\_iy_t$ =
i t i = 1 2 5 7 10

$r_{iy,t}$ = i
t i = 1 2 5 7 10

$r_{f,t}$ = (Risk free rate)
1
(repurchase rate)[1]

$B_{iy,t}$ = i t i = 1 2 5 7
10

y =

spot $\text{rate}_{y,t}$ = (Spot rate) i
t i = 1 2 5 7 10 [2]

---

[1] Repurchase rate www. thaibdc.or.th

[2] www. thaibdc.or.th

(2) (Slope of Term Structure Interest Rate) $slope_t$ (4.3)

$$slope_t = Interpolation\ GB\ yield_{10y,t} - Interpolation\ GB\ yield_{1y,t} \quad (4.3)$$

$slope_t$ = (Slope of Term Structure Interest Rate)

$Interpolation\ GB\ yield_{10y,t}$, = Interpolation of Government Bond Yield[3]

$Interpolation\ GB\ yield_{1y,t}$, 10 1 t

(3) (Excess Stock Return) $exre\_set_t$ (4.4)

$$exre\_set_t = r_{set,t} - r_{f,t}$$

$$r_{set,t} = \ln \frac{set\ index_t}{set\ index_{t-1}} \quad (4.4)$$

$exre\_set_t$ =

t

$r_{set,t}$ = t

$r_{f,t}$ = (risk free rate)

$set\ index_t$ = [4] t

3

2

2

[3] Interpolation of Government Bond Yield

www. bot.or.th

[4] SET Index www. set.or.th

bid-ask

4.2 __________

4.2.1 ____

(Stationary)

Stationary
Stationary Process (Mean)
(Variance)
Stationary $I(n)$ (Integrated Variable of Degree n) $n \geq 1$ $I(n \geq 1)$
n (n differencing) $I(0)$ Stationary

Unit Root Test
(Orders of Integration) Dickey and Fuller (1979) Autoregression
(4.5)

$$X_t = \rho X_{t-1} + \varepsilon_t \quad ; t = 1, 2, 3, \ldots\ldots, T \tag{4.5}$$

X_t =

ρ = (Lagged) X_{t-1}

ε_t = (Error Term) ε_t $N(0,\sigma^2)$

Stationary (ρ)

$|\rho|<1$ X X_t Stationary

$|\rho|\geq 1$ X X_t Non - Stationary

(Null Hypothesis) $\rho = 1$ (Alternative Hypothesis) $\rho < 1$

H_0 : $\rho = 1$ (Non - Stationary)

H_1 : $\rho < 1$ (Stationary)

Unit Root Test ρ 1

Null Hypothesis X_t

Non – Stationary ρ 1

X_t Stationary

Stationary

(Descriptive Statistics)

(Sample Mean = $\hat{\mu}$)

(Sample Standard Deviation = $\hat{\sigma}$)

(Sample Skewness = $\hat{S}$) (Sample Kurtosis Coefficient = $\hat{K}$) (Sample Correlation = $\hat{\rho}$)

(4.6)

$$\hat{\mu} = \frac{1}{T}\sum_{t=1}^{T} X_t \qquad \hat{S} = \frac{1}{\hat{\sigma}^3}\frac{\sum_{t=1}^{T}(X_t - \hat{\mu})^3}{T - 1}$$

$$\hat{\sigma}^2 = \frac{\sum_{t=1}^{T}(X_t - \hat{\mu})^2}{T - 1} \qquad \hat{K} = \frac{1}{\hat{\sigma}^4}\frac{\sum_{t=1}^{T}(X_t - \hat{\mu})^4}{T - 1} \tag{4.6}$$

$$\hat{\rho}(X,Y) = \frac{\hat{\sigma}_{xy}}{\sqrt{\hat{\sigma}_X^2 * \hat{\sigma}_Y^2}} \qquad \hat{\sigma}_{xy} = \frac{\sum_{t=1}^{T}(X_t - \hat{\mu}_X)(Y_t - \hat{\mu}_Y)}{T - 1}$$

(Sample Mean $= \hat{\mu}$)

(Sample Standard Deviation = $\hat{\sigma}$)

(Sample Skewness = $\hat{S}$)

(Sample Kurtosis Coefficient = $\hat{K}$)

3.00

3.00 3.00

Wald Test (W)

(4.7)

$$W = T\left[\frac{\hat{S}^2}{6} + \frac{(\hat{K}-3)^2}{24}\right] \tag{4.7}$$

W

2

99 W 9.21

4.2.2 Vector STAR

Vector STAR

(exre_set) (slope)
(exre_set) (4.1)
(Transition Function ; $G(S_t;\gamma,C)$)
Logistic (4.8) Quadratic Logistic (4.9)

Vector STAR

$$G(S_t;\gamma,C) = \frac{1}{1+\exp\left(\frac{-\gamma(S_t - C)}{\sigma_{S_t}}\right)} \quad ; \ \gamma > 0 \tag{4.8}$$

$$G(S_t;\gamma,C) = \frac{1}{1+\exp\left(\frac{-\gamma(S_t - C_1)(S_t - C_2)}{\sigma_{S_t}}\right)} \quad ; \ c_1 \le c_2 \ , \ \gamma > 0 \tag{4.9}$$

Vector STAR
Vector Autoregressive Model (VAR Model)
(4.10) VAR

$$\begin{bmatrix} exre\_iy_t \\ slope_t \\ exre\_set_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix} \sum_{j=1}^{P} \begin{bmatrix} \beta_{11}^{j} & \beta_{12}^{j} & \beta_{13}^{j} \\ \beta_{21}^{j} & \beta_{22}^{j} & \beta_{23}^{j} \\ \beta_{31}^{j} & \beta_{32}^{j} & \beta_{33}^{j} \end{bmatrix} \begin{bmatrix} exre\_iy_{t-j} \\ slope_{t-j} \\ exre\_set_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{bmatrix} \qquad (4.10)$$

VAR

(p) (Optimum Lag) LÜtkepohl (1991)

Likelihood Ratio Test LR (4.11)

$$LR = (T - C)\left(\log\left|\sum r\right| - \log\left|\sum u\right|\right) \quad H_0 \ \chi^2_{\alpha,df} \qquad (4.11)$$

T =

C = Unrestricted Model

$\log\left|\sum r\right| - \log\left|\sum u\right|$ = Log determinant Variance - Covariance matrix restricted unrestricted Model

H_0 : Restricted Model

H_1 : Unrestricted Model

H_0 LR Statistic χ^2

Restricted Model LR Statistic $\chi^2_{\alpha,df}$

(Null hypothesis: H_0) VAR Model

(Unrestricted Model) Degree of Freedom VAR Model 1 (Restricted Model)

VAR

VAR

(Linearity: against Vector STAR Model) (4.12)

$$Y_t = \alpha_t + \sum_{j=1}^{P}\Gamma_j^0 z_{t-j}^0 + \sum_{j=1}^{P}\Gamma_j^1 z_{t-j}^1 + \sum_{j=1}^{P}\Gamma_j^2 z_{t-j}^2 + \sum_{j=1}^{P}\Gamma_j^3 z_{t-j}^3 + \varepsilon_t \qquad (4.12)$$

(4.12) 2

VAR 2

(s_t) Vector STAR

3 $[exre\_y_{T-1},\ slope_{T-1},\ exrre\_set_{T-1}]$

(Linearity: against Vector STAR Model)

(s_t) 3 Wald Test

$H_{01}:\ \Gamma^1 = \Gamma^2 = \Gamma^3 = 0$

$H_{11}:\ \Gamma^1 \neq \Gamma^2 \neq \Gamma^3 \neq 0$

(s_t) Vector STAR

Vector STAR 3

4.2.3 Vector STAR

Vector STAR

Vector STAR

2

(1) Vector STAR

2 0 1

2 2 regimes

Vector STAR VAR

2 Vector

STAR (4.1)

$H_0: \beta_{jk}^1 = \beta_{jk}^2$; j k

$H_1: \beta_{jk}^1 \neq \beta_{jk}^2$; j k

β_{jk}^i = $\mathbf{Y_{k,t-j}}$; i = 1 2

Wald Test $\chi^2(h)$ h

(2) γ Vector STAR

$\gamma = 0$ $G(s_t) = \frac{1}{2}$

Vector STAR VAR

γ t-Statistic.

4.2.4 Vector STAR VAR

In-Sample Out-of Sample

Robustness Check 2

In-Sample Criteria Out-of Sample Criteria

In-Sample Out-of Sample

. . 1983

Meese and Rogoff (1983) . . 2003 Kilian and Taylor (2003)

In-Sample Out-of Sample

4.2.4.1 In-Sample

In-Sample

(Mean absolute Error: MAE)

(Root Mean Squared Error: RMSE)[5]

(4.14) (4.15)

$$\text{Mean Absolute Error} = \frac{\sum_{t=1}^{T} |e_t|}{T} \quad (4.14)$$

$$\text{Root Mean Squared Error} = \sqrt{\frac{\sum_{t=1}^{T} e_t^2}{T}} \quad (4.15)$$

e_t = t ; $e_t = (Y_t - \hat{Y}_t)$

Y_t = Y t

$\hat{Y}_t$ = Y_t

T =

4.2.4.2 Out of Sample

Out of Sample

Out of Sample 2

(1) Appending window sample squared prediction error

Appending

[5] Mean absolute Error Root Mean Squared Error Mean absolute Error Root Mean Squared Error

window Sample squared prediction error 1 R

(in sample) AR (β_{AR})

β_{AR} $\hat{Y}_{AR+1}$ $Error^2_{AR+1} = (Y_{R+1} - \hat{Y}_{AR+1})^2$

1 R+1 R+1 (β_{AR+1})

β_{AR+1} $\hat{Y}_{AR+2}$ $Error^2_{AR+2} = (Y_{AR+2} - \hat{Y}_{AR+2})^2$

T

$Error^2 = (Error^2_{AR+1} + Error^2_{AR+2} + ... + Error^2_T) \div (T - R)$ Appending window Sample squared prediction error

Appending window Sample squared prediction error

(2) Rolling mean squared prediction error

1 R (in sample)

RR (β_{RR}) β_{RR}

$\hat{Y}_{RR+1}$ $Error^2_{RR+1} = (Y_{R+1} - \hat{Y}_{RR+1})^2$ 2 R+1

R+1 (β_{RR+1}) β_{RR+1}

$\hat{Y}_{RR+2}$ $Error^2_{R+2} = (Y_{R+2} - \hat{Y}_{R+2})^2$ T

$Error^2 = (Error^2_{RR+1} + Error^2_{RR+2} + ... + Error^2_T) \div (T - R)$ Rolling mean squared prediction error

Rolling mean squared prediction error

Appending window Sample squared prediction error Rolling mean squared prediction error

Appending window Sample squared prediction error

Rolling mean squared prediction error Rolling mean squared prediction error

Appending window Sample squared prediction error Rolling mean squared prediction error

2 R

Vector STAR

R = 1,000

300

Vector STAR VAR Out of Sample (out of sample test of predictive ability) VAR Vector STAR

Appending window sample squared prediction errors Rolling mean squared prediction errors [6]

H_{10} : Appending window Sample $\text{SPE}_{\text{VAR}} =$ Appending window Sample $\text{SPE}_{\text{Vector STAR}}$

H_{11} : Appending window Sample $\text{SPE}_{\text{VAR}} \neq$ Appending window Sample $\text{SPE}_{\text{Vector STAR}}$

H_{20} : Rolling $\text{MSPE}_{\text{VAR}} =$ Rolling $\text{MSPE}_{\text{Vector STAR}}$

H_{21} : Rolling $\text{MSPE}_{\text{VAR}} \neq$ Rolling $\text{MSPE}_{\text{Vector STAR}}$

Diebold and Mariano (1995) West (1996) Out of Sample MSE (4.16)

$$MSE = P^{1/2} \text{ x } \frac{P^{-1}\sum_{t=1}^{P}\left(\hat{e}^2_{STAR,t} - \hat{e}^2_{VAR,t}\right)}{\sqrt{P^{-1}\sum_{t=1}^{P}\left(\hat{e}^2_{STAR,t} - \hat{e}^2_{VAR,t}\right)^2}} \quad H_0 \; N(0,1) \qquad (4.16)$$

---

[6] Appending window sample squared prediction errors Rolling mean squared prediction errors

$e^2_{VAR,t}$ = VAR t

(Forecast Error); $e^2_{VAR,t} = Y_t - \hat{Y}_{VAR,t}$

$e^2_{STAR,t}$ = STAR

t (Forecast Error); $e^2_{STAR,t} = Y_t - \hat{Y}_{STAR,t}$

Y_t = Y t

$\hat{Y}_{VAR,t}$ = Y_t VAR

$\hat{Y}_{STAR,t}$ = Y_t STAR

P = Out of Sample (the number of 1-step of ahead prediction out of sample)

Null Hypothesis (H_0) VAR Vector STAR MSE

Out of Sample VAR Vector STAR

5

5.1

Stationary Augmented
Dickey-Fuller (ADF) Test (Null Hypothesis) Nonstationary
ADF-
Statistics MacKinnon Critical Value (At Level)
Nonstationary Homogeneous Nonstationary
Stationary
5.1 Unit Root (At Level)
ADF-statistic
MacKinnon Critical Value 99 95 90
Stationary
(slope) Nonstationary
(At Level) 1 (At First Difference)
Unit Root
(slope) I(1) 1

5.2
1 2 5 7
10 (exre_iy) (dif_slope)
(exre_set) Wald-Test
9.21
(Normal distribution)
Maximum likelihood Estimator (MLE)
asymptotic properties (Green (2003))

3

fat tail

5.2

1.57

(high risk high return)

5.2

(2547)

(Correlation) 5.3

5.3

1 3 6 12

5.2

Vector STAR

5.1

Stationary Unit Root

(At Level)

	ADF	1% Mackinnon	5% Mackinnon	10% Mackinnon	
exre_1y	-8.02311	-3.435211	-2.863574	-2.567903	Stationary
exre_2y	-22.11812	-3.435169	-2.863556	-2.567893	Stationary
exre_5y	-17.26935	-3.435176	-2.863559	-2.567894	Stationary
exre_7y	-25.97411	-3.435169	-2.863559	-2.567893	Stationary
exre_10y	-24.75266	-3.435169	-2.863556	-2.567893	Stationary
slope	-2.328593	-3.435188	-2.863564	-2.567897	Nonstationary
dif_slope	-11.797905	-3.435184	-2.893562	-2.567896	Stationary
exre_set	-17.78286	-3.435215	-2.863576	-2.567904	Stationary

5.2

	exre_1y	exre_2y	exre_5y	exre_7y	exre_10y	dif_slope	exre_set
(Mean)	-0.00297	-0.00145	0.00457	0.01034	0.01927	-4.16E-06	-0.02860
(Median)	-0.00253	-0.00152	0.00843	0.01200	0.02140	-8.48E-06	0.02179
(Maximum)	0.22743	0.39365	1.25198	2.23327	2.94793	0.00139	5.42323
(Minimum)	-0.33947	-1.10796	-3.68799	-3.71744	-5.86450	-0.00067	-7.34717
	0.02573	0.07803	0.30366	0.43765	0.56260	0.00014	1.56849
(Skewness)	-2.89333	-4.37075	-2.58137	-1.75550	-2.00725	1.42145	-0.26319
(Kurtosis)	50.66884	54.36495	28.61915	16.62411	21.37974	16.96349	4.66178
Wald Test	124,993.8	147,163.3	37,024.0	10,730.12	19,186.0	11,007.60	164.7
P-value	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(-0.005)**	(0.000)**

: p - value ( ) : ** 0.05

5.3

	exre_1y	exre_2y	exre_5y	exre_7y	exre_10y	dif_slope	exre_set
exre_1y	1	0.75162	0.62266	0.54417	0.46743	-0.01256	-0.00565
exre_2y	0.75162	1	0.80837	0.69612	0.59898	-0.28898	0.04845
exre_5y	0.62266	0.80837	1	0.89530	0.78665	-0.56804	0.03326
exre_7y	0.54417	0.69612	0.89530	1	0.88875	-0.72423	0.01502
exre_10y	0.46743	0.59898	0.78665	0.88875	1	-0.88962	0.00866
dif_slope	-0.01256	-0.28898	-0.56804	-0.72423	-0.88962	1	-0.06809
exre_set	-0.00565	0.04845	0.03326	0.01502	0.00866	-0.06809	1

5.2 Vector STAR

5.4

1 95 LR Statistic χ^2 (12)
5.5 VAR (1)
1 2 5 7 10

5.4
Likelihood Ratio Test

	Determinant residual Covariance		LR	
	Unrestricted (21)	restricted (12)		
	lag 2	lag 1		
exre_1y	2.27E-11	2.28E-11	2.44160	lag1
exre_2y	1.76E-10	1.79E-10	9.38832	lag1
exre_5y	2.19E-09	2.24E-09	12.53919	lag1
exre_7y	3.40E-09	3.44E-09	6.49671	lag1
exre_10y	2.26E-09	2.28E-09	4.89398	lag1

: - ((H_0) Restricted Model

- LR-statistic $\chi^2_{\alpha,df}$

- χ^2 (12) 5 22.3621

5.5

VAR

1

	C	exre_1y(-1)	dif_slope(-1)	exre_set (-1)	Sum sq. Residuals
exre_1y	-0.00184	0.39096	-13.89994	-0.00074	0.72199
	(-2.7831)*	(15.3658)**	(-2.8891)*	(-1.7696)	
dif_slope	-2.62E-06	8.87E-05	0.32002	2.08E-06	2.16E-05
	(-0.7263)	(0.6372)	(12.1618)**	(0.9122)	
exre_set	0.02571	-0.87889	-96.74220	0.05169	3184.596
	(0.5872)	(-0.5201)	(-0.3028)	(1.8645)	

5. 5

VAR

2

	C	exre_2y(-1)	dif_slope(-1)	exre_set (-1)	Sum sq. Residuals
exre_2y	-0.00094	0.43124	-46.13821	-0.00192	6.23402
	(-0.4871)	(16.7287)**	(-3.1247)**	(-1.5647)	
dif_slope	-2.69E-06	8.7E-05	0.33419	1.88E-06	2.15E-05
	(-0.7515)	(1.8146)	(12.1738)**	(0.8235)	
exre_set	0.02774	-0.26047	-137.7128	0.05235	3184.769
	(0.6374)	(-0.4471)	(-0.4126)	(1.8864)	

5. 5

VAR

5

	C	exre_5y(-1)	dif_slope(-1)	exre_set (-1)	Sum sq. Residuals
exre_5y	0.00249	0.32280	-181.7582	-0.01129	102.7475
	(0.3517)	(10.3248)**	(-2.6065)*	(-2.2662)	
dif_slope	-2.82E-06	9.6E-05	0.33206	2.03E-06	2.16E-05
	(-0.8022)	(0.6748)	(10.3871)**	(0.8867)	
exre_set	0.02837	0.06058	-17.87892	0.05146	3184.963
	(0.6520)	(0.3481)	(-0.0461)	(1.8554)	

5. 5

VAR

7

	C	exre_7y(-1)	dif_slope(-1)	exre_set (-1)	Sum sq. Residuals
exre_7y	0.007344	0.29555	-94.23595	-0.01422	223.3807
	(0.6374)	(7.7453)**	(-0.7679)	(-1.9368)	
dif_slope	-2.88E-06	-6.55E-05	0.30454	2.09E-06	2.16E-05
	(-0.8031)	(-0.5524)	(7.9813)**	(0.9134)	
exre_set	0.02875	0.05915	43.13160	0.05167	3184.846
	(0.6500)	(0.4105)	(0.0931)	(1.8637)	

5. 5

VAR

10

	C	exre_10y(-1)	dif_slope(-1)	exre_set (-1)	Sum sq. Residuals
exre_10y	0.01285	0.360167	5.22521	-0.01486	357.8135
	(0.8811)	(6.3495)**	(0.0223)	(-1.5991)	
dif_slope	-2.92E-06	8.16E-05	0.34982	2.08E-06	2.16E-05
	(-0.8136)	(0.5855)	(6.0712)**	(0.9116)	
exre_set	0.02866	-0.08457	-405.6689	0.05169	3184.647
	(0.6588)	(-0.4997)	(-0.5798)	(1.8649)	

: ( ) t-statistics

: ** 0.05

: * 0.1

5.5 VAR

(dif_slope)

(1 2) Evans and Lewis
(1994) (5 7 10)

VAR
(exre_set)

5.5
VAR

5.5

VAR

5.6

Wald test

$$H_{01}: \Gamma^1 = \Gamma^2 = \Gamma^3 = 0$$

1

99
Vector STAR

5.7 Wald-Test

1 2 5

7 Wald test $H_{04}: \Gamma^3 = 0$ (p-value)

Logistic Vector STAR

10 Wald

test $H_{03}: \Gamma^2 = 0 \mid \Gamma^3 = 0$ (p-value)

Quadratic Logistic

2

( )

1 2 5 7

Lekkos and Milas (2004)

10

5.8

Vector STAR 5

5.8 Vector STAR

5.9

Vector STAR 2

99 γ

Vector STAR (Regime Switching)

VAR

VAR

5.6

Wald Test

		$H_{01}: \Gamma^1 = \Gamma^2 = \Gamma^3 = 0$	
exre_1y Model	*exre_1y(-1)*	227.2839	*exre_1y(-1)*
	dif_slope1(-1)	27.27095	
	exre_set(-1)	92.34149	
exre_2y Model	*exre_2y(-1)*	187.0872	*exre_2y(-1)*
	dif_slope1(-1)	83.35185	
	exre_set(-1)	43.91100	
exre_5y Model	*exre_5y(-1)*	199.5671	*exre_5y(-1)*
	dif_slope1(-1)	35.7400	
	exre_set(-1)	113.0407	
exre_7y Model	*exre_7y(-1)*	116.8807	*exre_7y(-1)*
	dif_slope1(-1)	45.73366	
	exre_set(-1)	36.00404	
exre_10y Model	*exre_10y(-1)*	65.46941	*exre_10y(-1)*
	dif_slope1(-1)	54.76909	
	exre_set(-1)	28.01244	

: Wald p – value

5.7

Wald Test (Transition Function)

		$H_{04}: \beta^3=0$	$H_{03}: \beta^2=0 \mid \beta^3=0$	$H_{02}: \beta^1=0 \mid \beta^2=\beta^3=0$	
exre_1y Model	*exre_1y(-1)**	97.96534	74.6609	43.38610	*LSTAR*
exre_2y Model	*exre_2y(-1)**	80.97796	60.99587	37.3898	*LSTAR*
exre_5y Model	*exre_5y(-1)**	85.18980	26.07079	80.02779	*LSTAR*
exre_7y Model	*exre_7y(-1)**	80.32219	24.37010	10.97335	*LSTAR*
exre_10y Model	*exre_10y(-1)**	16.67215	18.20133	11.71346	*ESTAR*

: Wald p – value

5.8

Vector STAR

exre_1y Model

$$exre\_1y_t = (-0.00392 + 0.32168 exre\_1y_{t-1} - 27.621 \text{dif\_slope}_{t-1} - 0.00046 \text{exre\_set}_{t-1})(1 - G(exre\_2y_{t-1};\gamma,c_1)) +$$

(0.0000)** (0.0000)** (0.0000)** (0.4689)

$$(-0.00027 + 0.3979 exre\_1y_{t-1} + 5.7483 \text{dif\_slope}_{t-1} - 0.00099 \text{exre\_set}_{t-1}) G(exre\_2y_{t-1};\gamma,c_1)$$

(0.3723) (0.0000)** (0.10197)* (0.0028)**

$$G(exre\_1y_{t-1};c_1) = \left\{1+\exp\left[-36.977(exre\_1y_{t-1} - 0.00248)/0.0257\right]\right\}^{-1}$$

(0.0000)* (0.0000)*

exre_2y Model

$$exre\_2y_t = (0.30643 + 0.71633 exre\_2y_{t-1} - 413.322 \text{dif\_slope}_{t-1} + 0.02328 \text{exre\_set}_{t-1})(1 - G(exre\_2y_{t-1};\gamma,c_1)) +$$

(0.0000)** (0.0000)** (0.0000)** (0.0000)**

$$(-0.00184 + 0.5384 exre\_2y_{t-1} - 1.9698 \text{dif\_slope}_{t-1} - 0.00023 \text{exre\_set}_{t-1}) G(exre\_2y_{t-1};\gamma,c_1)$$

(0.1067)* (0.0057)** (0.41357) (0.002)**

$$G(exre\_2y_{t-1};\gamma,c_1) = \left\{1+\exp\left[-3.5672(exre\_2y_{t-1} - 0.25692)/0.0781\right]\right\}^{-1}$$

(0.0000)* (0.0000)*

exre_5y Model

$$exre\_5y_t = (0.85243 + 0.51234 exre\_5y_{t-1} - 315.98 \text{dif\_slope}_{t-1} + 1.0364 \text{exre\_set}_{t-1})(1 - G(exre\_5y_{t-1};\gamma,c_1)) +$$

(0.0000)** (0.0176)** (0.0000)** (0.0001)**

$$(-0.8317 + 0.14352 exre\_5y_{t-1} - 59.854 \text{dif\_slope}_{t-1} - 1.0415 \text{exre\_set}_{t-1}) G(exre\_5y_{t-1};\gamma,c_1)$$

(0.0000)** (0.2789) (0.0060)** (0.0000)**

$$G(exre\_5y_{t-1};\gamma,c_1) = \left\{1+\exp\left[-0.0066(exre\_5y_{t-1} - 0.79851/0.30366\right]\right\}^{-1}$$

(0.0000)** (0.0000)**

5. 8[1] ( )

Vector STAR

exre_7y Model

$$exre\_7y_t = (-1.8492 + 0.03259 exre\_7y_{t-1} - 20.957 dif\_slope_{t-1} + 0.11376 exre\_set_{t-1})(1 - G(exre\_7y_{t-1};\gamma,c_1)) +$$

(0.0000)** (0.22673) (0.0000)** (0.0001)**

$$(2.5150 - 0.38982 exre\_7y_{t-1} - 4.0238 dif\_slope_{t-1} - 0.18507 exre\_set_{t-1}) G(exre\_7y_{t-1};\gamma,c_1)$$

(0.0000)** (0.0000)** (0.0060)** (0.0000)**

$$G(exre\_7y_{t-1};\gamma,c_1) = \left\{1+\exp\left[-0.18926(exre\_7y_{t-1} + 0.69039)/0.4378\right]\right\}^{-1}$$

(0.0000)** (0.0000)**

exre_10y Model

$$exre\_10y_t = (18.6860 + 49.6450 exre\_10y_{t-1} - 14.9590 dif\_slope_{t-1} + 2.9437 exre\_set_{t-1})(1 - G(exre\_10y_{t-1};\gamma,c_1)) +$$

(0.0000)* (0.0000)* (0.0000)* (0.0000)*

$$(-18.6510 - 48.7970 exre\_10y_{t-1} - 0.91173 dif\_slope_{t-1} - 2.9768 exre\_set_{t-1}) G(exre\_10y_{t-1};\gamma,c_1)$$

(0.0000)* (0.0000)* (0.0060)* (0.0000)*

$$G(exre\_10y_{t-1};\gamma,c_1) = \left\{1+\exp\left[-0.00028(exre\_10y_{t-1} - 0.44548)(exre\_10y_{t-1} - 1.7569)/0.5626\right]\right\}^{-1}$$

(0.0000)* (0.0000)* (0.0000)*

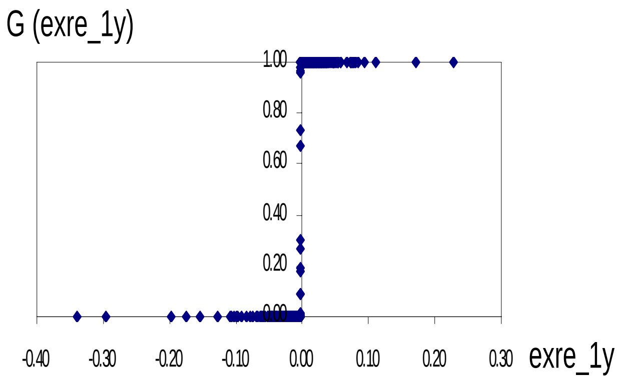
: P-value ( )

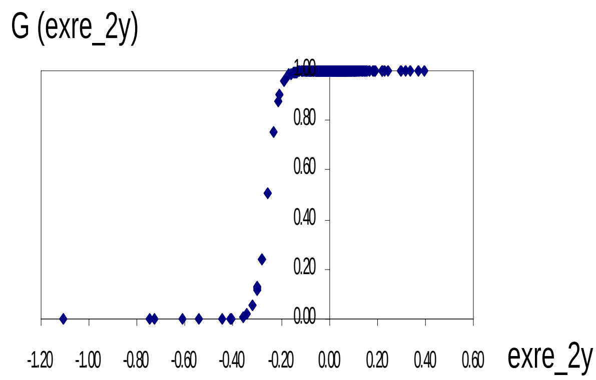
: ** 0.05

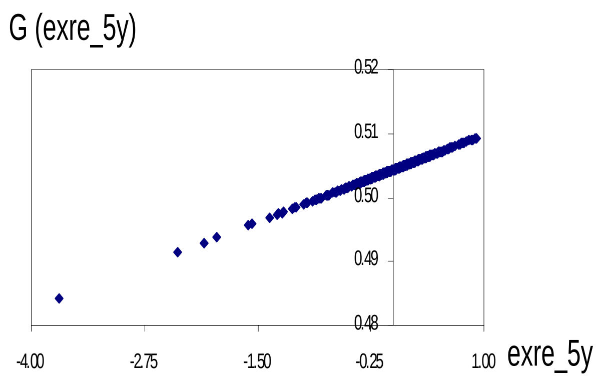
: * 0.1

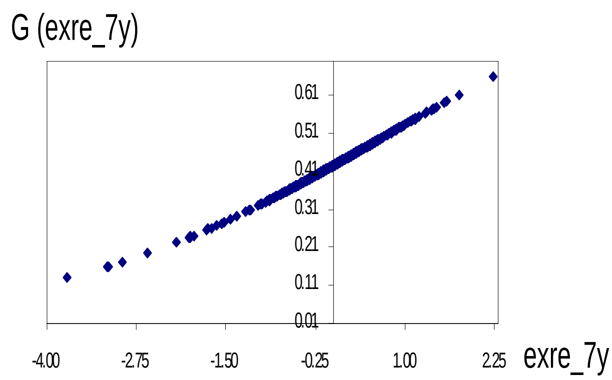
1 Vector STAR

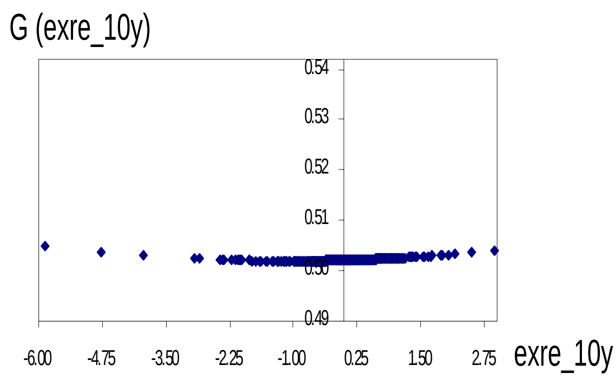
5.1


G (exre_1y)
1.00
0.80
0.60
0.40
0.20
0.00
-0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30
exre_1y


G (exre_2y)
1.00
0.80
0.60
0.40
0.20
0.00
-1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60
exre_2y


G (exre_5y)
0.52
0.51
0.50
0.49
0.48
-4.00 -2.75 -1.50 -0.25 1.00
exre_5y


G (exre_7y)
0.61
0.51
0.41
0.31
0.21
0.11
0.01
-4.00 -2.75 -1.50 -0.25 1.00 2.25
exre_7y


G (exre_10y)
0.54
0.53
0.52
0.51
0.50
0.49
-6.00 -4.75 -3.50 -2.25 -1.00 0.25 1.50 2.75
exre_10y

5.9

STAR

	$H_0: \beta^1_{jk} = \beta^2_{jk}$		$H_0: \gamma = 0$	
	Wald Test	Result	t-test	Result
exre_1y Model	53.96	Reject H_0	10.92	Reject H_0
exre_2y Model	347.89	Reject H_0	3.56	Reject H_0
exre_5y Model	2,283.90	Reject H_0	15.05	Reject H_0
exre_7y Model	2,266.50	Reject H_0	40.67	Reject H_0
exre_10y Model	485.64	Reject H_0	9.29	Reject H_0

: P-value ( ) **

0.05

VAR Vector STAR Vector STAR LSTAR ESTAR

1 2 5 7 LSTAR $G(exre\_iy_{t-1})$

[2]

LSTAR 2

LSTAR

1

2

2 LSTAR

1 LSTAR

5.2
2

10 ESTAR
$G(exre\_iy_{t-1})$
ESTAR

10
ESTAR 2

10
10

ESTAR 1
10
2 ESTAR
10
1 ESTAR
10

5.8
Vector STAR

Campbell and Shiller (1987) Evans and Lewis (1994)
Lekkos and Milas (2004)
1 2
(dif_slope)
5 7
(dif_slope)

10

LSTAR
5 7
regime 1 regime 2

5 7

(Yield)

10 ESTAR LSTAR

10

(exre_set)

Vector STAR

1

2 5 7

Campbell and Ammer (1993)

10

Connolly, Stivers and Sun (2005)

2

5.3 Vector STAR VAR

5.10 Vector STAR

VAR In sample MAE RMSE

MAE RMSE VAR MAE RMSE

Vector STAR In sample Vector STAR

VAR Out of sample Appending Window

Sample Squared Prediction Errors Rolling Mean Squared Prediction Error

(1)

Appending Window Sample

Squared Prediction Errors Rolling Mean Squared Prediction Error VAR

Appending Window Sample Squared Prediction Errors Rolling
Mean Squared Prediction Error Vector STAR
Vector STAR VAR MSE Test
5.11 1 p-
value 0.05
Vector STAR VAR
1 0.05
2 5 7 10 p-value 0.05
Vector STAR
VAR 0.05
Out of sample VAR
Vector STAR

In Sample Out of
Sample
Out of Sample

5.10
Vector STAR VAR

Model	*exre_1y Model*		*exre_2y Model*		*exre_5y Model*		*exre_7y Model*		*exre_10y Model*	
	LSTAR	*VAR*	*LSTAR*	*VAR*	*LSTAR*	*VAR*	*LSTAR*	*VAR*	*ESTAR*	*VAR*
In sample										
MAE	0.0508	0.0507	0.1451	0.1494	0.7298	0.72989	1.0841	1.0877	1.3731	1.3749
RMSE	0.0486	0.0489	0.1386	0.1439	0.5841	0.58425	0.85902	0.86147	1.0807	1.0903
Out of sample										
Appending Window Sample Squared Prediction Errors										
1000	0.0004	0.0004	0.0085	0.0055	0.1167	0.0722	0.1729	0.1719	4.9851	0.2579
Rolling Mean Squared Prediction Errors										
1000	0.0004	0.0004	0.0096	0.0055	0.1292	0.0730	0.2131	0.1727	8.1597	0.2590

5.11

Vector STAR

VAR

	H_{10}		H_{20}	
	MSE-Test	p-value	MSE-	p-value
exre_1y Model	-0.6289	0.2647	-0.4878	0.3129
exre_2y Model	5.1150	0.0000**	5.6068	0.0000**
exre_5y Model	3.8539	0.0001**	6.1533	0.0000**
exre_7y Model	1.6416	0.0503	5.2009	0.0000**
exre_10y Model	2.0657	0.0194**	1.5164	0.0647

: ** 0.05

6

6.1

6.1.1

Vector STAR (Smooth Transition Autoregression) 5
1 2 5 7 10

(Nonlinearity)
(Regime switching behavior)
(Time Varying)
(regimes)
2

1 2 5 7

10
(10)

(exre_iy)
(dif_slope) (exre_set)

6.1.2 ________

6.1.2.1 ข้อเสนอแนะจากการศึกษา

1.

VAR

Vector STAR

VAR

2.

3.

(Portfolio)

4. Vector STAR

6.1.2.2 ข้อเสนอแนะจากการศึกษาในอนาคต

1. Vector STAR

Vector STAR

2.

6.2 _______________

1. 5

Vector STAR

.[1]

STAR

STAR *(1)*

$$Y_T = \mu_0 + \sum_{j=1}^{p} \phi_{0,j} Y_{T-j} + \sum_{j=1}^{p} \phi_{1,j} Y_{T-j} s_t + \sum_{j=1}^{p} \phi_{2,j} Y_{T-j} s^2_t + \sum_{j=1}^{p} \phi_{3,j} Y_{T-j} s_t^3 + \varepsilon_T$$

$$y\_i_t = (\mu_1 + \phi_{1,j} W_{t-j})(1 - G(S_t)) + (\mu_2 + \phi_{2,j} W_{t-j}) G(S_t) + \varepsilon_t$$

$$Y_T = \mu_0 + \sum_{j=1}^{p} \phi_{0,j} Y_{T-j} + \sum_{j=1}^{p} \phi_{1,j} Y_{T-j} s_t + \sum_{j=1}^{p} \phi_{2,j} Y_{T-j} s^2_t + \sum_{j=1}^{p} \phi_{3,j} Y_{T-j} s_t^3 + \varepsilon_T$$

$$= (\mu_1 + \phi_{1,j} W_{t-j}) + \{ (\mu_2 - \mu_1)(\phi_{2,j} - \phi_{1,j}) \} G(S_t) + \varepsilon_t \qquad (1)$$

$G(s_t)$ Third-order Taylor Approximation $\gamma = 0$ เมื่อ $G(s_t)$ เป็น *Logistic Function*

---

[1] Transition Function

Granger, C. W. J., and T. Teräsvirta, 1993 114

$$G(s_t) = \frac{1}{1 + \exp \frac{-\gamma(S_t - c)}{\sigma(S_t)}} \quad ; \ \gamma > 0$$

$$G(s_t) \ . \ G(\gamma = 0) + G'(\gamma = 0)(\gamma - 0) + \frac{1}{2!}G''(\gamma = 0)(\gamma - 0)^2 + \frac{1}{3!}G'''(\gamma = 0)(\gamma - 0)^3$$

$$. \ \frac{1}{2} + \frac{1}{2} \ \frac{(S_t - c)}{b} \ \gamma + 0 + \frac{\gamma^3}{6}\left\{-\frac{1}{8b^3}(S_t^3 - 3cS_t^2 + 3c^2S_t - c^2)\right\} \quad ; \ \sigma(s_t) = b$$

$$. \left\{-\frac{1}{2} - \frac{c\gamma}{4b} + \frac{1}{48b^3}c^3\gamma\right\} + \ \frac{\gamma}{4b} - \frac{c^2\gamma}{16b^3} \ S_t + \left\{\frac{c\gamma}{16b^3}\right\}S_t^2 + \left\{\frac{-\gamma}{48b^3}\right\}S_t^3$$

$$. \ \{A\} + \{B\}S_t + \{C\}S_t^2 + \{D\}S_t^3 \qquad (2)$$

โดยที่

$$A = \left\{-\frac{1}{2} - \frac{c\gamma}{4b} + \frac{1}{48b^3}c^3\gamma\right\} \qquad C = \left\{\frac{c\gamma}{16b^3}\right\}$$

$$B = \ \frac{\gamma}{4b} - \frac{c^2\gamma}{16b^3} \qquad D = \left\{\frac{-\gamma}{48b^3}\right\}$$

(2) *(1)* *(3)*

$$y\_i_t = (\mu_1 + \phi'_{1,j} W_{t-j}) + \left\{ (\mu_2 - \mu_1) + (\phi_{2,j} - \phi_{1,j})' W_{t-j} \right\} (A + BS_t + CS_t^2 + DS_t^3) + \varepsilon_t$$

$$= (\mu_1 + \phi'_{1,j} W_{t-j}) + (\mu_2 - \mu_1)(A + BS_t + CS_t^2 + DS_t^3) +$$
$$(\phi_{2,j} - \phi_{1,j})' W_{t-j} (A + BS_t + CS_t^2 + DS_t^3) + \varepsilon_t$$

$$= \left\{ \mu_1 + (\mu_2 - \mu_1)(A + BS_t + CS_t^2 + DS_t^3) \right\} + \left\{ \mu_1 + (\mu_2 - \mu_1) A \right\}' W_{t-j} +$$
$$\left\{ (\phi_{2,j} - \phi_{1,j}) B \right\}' W_{t-j} S_t + \left\{ (\phi_{2,j} - \phi_{1,j}) C \right\}' W_{t-j} S_t^2 + \left\{ (\phi_{2,j} - \phi_{1,j}) D \right\}' W_{t-j} S_t^3$$

$$y\_i_t = \left\{ \mu_1 + (\mu_2 - \mu_1) G(S_t) \right\} + \left\{ B_0 \right\}' W_{t-j} + \left\{ B_1 \right\}' W_{t-j} S_t + \left\{ B_2 \right\}' W_{t-j} S_t^2 + \left\{ B_3 \right\}' W_{t-j} S_t^3 + \varepsilon_t \qquad (3)$$

$$B_0 = \mu_1 + (\mu_2 - \mu_1) \left\{ -\frac{1}{2} - \frac{c\gamma}{4b} + \frac{1}{48b^3} c^3 \gamma \right\} \qquad B_2 = (\phi_{2,j} - \phi_{1,j}) \left\{ \frac{c\gamma}{16b^3} \right\}$$

$$B_1 = (\phi_{2,j} - \phi_{1,j}) \quad \frac{\gamma}{4b} - \frac{c^2 \gamma}{16b^3} \qquad B_3 = (\phi_{2,j} - \phi_{1,j}) \left\{ \frac{-\gamma}{48b^3} \right\}$$

เมื่อ $G(s_t)$ *เป็น Quadratic Logistic Function*

$$G(s_t) = \frac{1}{1+\exp\ \frac{-\gamma(S-c_1)(S-c_2)}{\sigma(s_t)}} \quad ; \ c_1 \le c_2 \ , \ \gamma > 0$$

$$G(s_t) \approx G(\gamma=0) + G'(\gamma=0)(\gamma-0) + \frac{1}{2!}G''(\gamma=0)(\gamma-0)^2 + \frac{1}{3!}G'''(\gamma=0)(\gamma-0)^3$$

$$\approx \frac{1}{2}+\frac{1}{4b}\ \frac{(S-c_1)(S-c_2)}{b^2}\ \gamma+\frac{\gamma^2}{4}(0)+\frac{\gamma^3}{6}\ -\frac{1}{8b^3}\ \begin{array}{l} S_t^6-3c_2S_t^5+3c_2^2S_t^4-c_2^3S_t^3-3c_1S_t^5 \\ +9c_1c_2S_t^4-9c_1c_2^2S_t^3+3c_1c_2^2S_t^2 \\ +3c_1^2S_t^4-9c_1^2c_2S_t^3+9c_1^2c_2^2S_t^2 \\ -3c_1^2c_2^3S_t-c_1^3S_t^3-3c_1^2c_2S_t^2 \\ -3c_1^2c_2S_t+c_1^2c_2^3 \end{array}$$

โดยที่ $;\sigma^2(s_t) = b$

$$\approx \ \frac{1}{2}+\frac{c_1c_2\gamma}{4b}-\frac{c_1^3c_2^3\gamma^3}{48b^3} \ + \ \frac{-c_2\gamma}{4b}-\frac{c_1\gamma}{4b}+\frac{c_1^2c_2^2\gamma^3}{16b^3}+\frac{c_1^2c_2^3\gamma^3}{16b^3}\ S_t +$$
$$\frac{\gamma}{4}-\frac{c_1c_2^3\gamma^3}{16b^3}-\frac{3c_1^2c_2^2\gamma^3}{16b^3}-\frac{3c_1^2c_2\gamma^3}{16b^3}\ S_t^2 + \frac{c_2^3\gamma^3}{48b^3}+\frac{3c_1c_2^2\gamma^3}{16b^3}+\frac{3c_1^2c_2\gamma^3}{16b^3}-\frac{c_1^3\gamma^3}{48b^3}\ S_t^3 +$$
$$\frac{-3c_2^2\gamma^3}{48b^3}-\frac{3c_1c_2\gamma^3}{16b^3}-\frac{3c_1^2\gamma^3}{48b^3}\ S_t^4+\ \frac{c_2\gamma^3}{16b^3}-\frac{c_1\gamma^3}{16b^3}\ S_t^5+\ \frac{-\gamma^3}{48b^3}\ S_t^6$$

$$\approx \ \frac{1}{2}+\frac{c_1c_2\gamma}{4b}-\frac{c_1^3c_2^3\gamma^3}{48b^3} \ + \ \frac{-\gamma}{4b}(c_2-c_1)+\frac{\gamma^3}{16b^3}(c_1^2c_2^2+c_1^2c_2^3)\ S_t +$$
$$\frac{\gamma}{4}-\frac{\gamma^3}{16b^3}(c_1c_2^3+3c_1^2c_2^2+3c_1^2c_2)\ S_t^2 + \frac{\gamma^3}{48b^3}(c_2^3+3c_1c_2^2+3c_1^2c_2-c_1^3)\ S_t^3 +$$
$$\frac{-\gamma^3}{48b^3}(3c_2^2+9c_1c_2+3c_1^2)\ S_t^4+\ \frac{\gamma^3}{16b^3}(c_2+c_1)\ S_t^5+\ \frac{-\gamma^3}{48b^3}\ S_t^6$$

$$G(s_t) \approx E+FS_t+HS_t^2+IS_t^3+JS_t^4+KS_t^5+LS_t^6 \qquad (4)$$

$$E = \frac{1}{2} + \frac{c_1 c_2 \gamma}{4b} - \frac{c_1^3 c_2^3 \gamma^3}{48b^3} \qquad J = \frac{-\gamma^3}{48b^3}(3c_2^2 + 9c_1c_2 + 3c_1^2)$$

$$F = \frac{-\gamma}{4b}(c_2 - c_1) + \frac{\gamma^3}{16b^3}(c_1^2c_2^2 + c_1^2c_2^3) \qquad K = \frac{\gamma^3}{16b^3}(c_2 + c_1)$$

$$H = \frac{\gamma}{4} - \frac{\gamma^3}{16b^3}(c_1c_2^3 + 3c_1^2c_2^2 + 3c_1^2c_2) \qquad L = \frac{-\gamma^3}{48b^3}$$

$$I = \frac{\gamma^3}{48b^3}(c_2^3 + 3c_1c_2^2 + 3c_1^2c_2 - c_1^3)$$

(4) *(1)* *(5)*

$$y\_i_t = (\mu_1 + \phi_{1,j}' W_{t-j}) + \left\{ (\mu_2 - \mu_1) + (\phi_{2,j} - \phi_{1,j})' W_{t-j} \right\} (E + FS_t + HS_t^2 + IS_t^3 + JS_t^4 + KS_t^5 + LS_t^6) + \varepsilon_t$$

$$= (\mu_1 + \phi_{1,j}' W_{t-j}) + (\mu_2 - \mu_1)(E + FS_t + HS_t^2 + IS_t^3 + JS_t^4 + KS_t^5 + LS_t^6) + (\phi_{2,j} - \phi_{1,j})' W_{t-j}(E + FS_t + HS_t^2 + IS_t^3 + JS_t^4 + KS_t^5 + LS_t^6) + \varepsilon_t$$

$$= \left\{ \mu_1 + (\mu_2 - \mu_1)(E + FS_t + HS_t^2 + IS_t^3 + JS_t^4 + KS_t^5 + LS_t^6) \right\} + \left\{ \phi_{1,j} + (\phi_{2,j} - \phi_{1,j})E \right\}' W_{t-j} + \left\{ (\phi_{2,j} - \phi_{1,j})F \right\}' W_{t-j} S_t + \left\{ (\phi_{2,j} - \phi_{1,j})H \right\}' W_{t-j} S_t^2 + \left\{ (\phi_{2,j} - \phi_{1,j})I \right\}' W_{t-j} S_t^3 + \left\{ (\phi_{2,j} - \phi_{1,j})J \right\}' W_{t-j} S_t^4 + \left\{ (\phi_{2,j} - \phi_{1,j})K \right\}' W_{t-j} S_t^5 + \left\{ (\phi_{2,j} - \phi_{1,j})L \right\}' W_{t-j} S_t^6$$

$$y\_i_t = \left\{ \mu_1 + (\mu_2 - \mu_1)G(S_t) \right\} + \left\{ B_0 \right\}' W_{t-j} + \left\{ B_1 \right\}' W_{t-j} S_t + \left\{ B_2 \right\}' W_{t-j} S_t^2 + \left\{ B_3 \right\}' W_{t-j} S_t^3 + \left\{ B_4 \right\}' W_{t-j} S_t^4 + \left\{ B_5 \right\}' W_{t-j} S_t^5 + \left\{ B_6 \right\}' W_{t-j} S_t^6 + \varepsilon_t \qquad (5)$$

$$B_0 = \phi_{1,j} + (\phi_{2,j} - \phi_{1,j}) \;\; \frac{1}{2} + \frac{c_1 c_2 \gamma}{4b} - \frac{c_1^3 c_2^3 \gamma^3}{48b^3}$$

$$B_1 = (\phi_{2,j} - \phi_{1,j}) \;\; \frac{-\gamma}{4b}(c_2 - c_1) + \frac{\gamma^3}{16b^3}(c_1^2 c_2^2 + c_1^2 c_2^3)$$

$$B_2 = (\phi_{2,j} - \phi_{1,j}) \;\; \frac{\gamma}{4} - \frac{\gamma^3}{16b^3}(c_1 c_2^3 + 3c_1^2 c_2^2 + 3c_1^2 c_2)$$

$$B_3 = (\phi_{2,j} - \phi_{1,j}) \;\; \frac{\gamma^3}{48b^3}(c_2^3 + 3c_1 c_2^2 + 3c_1^2 c_2 - c_1^3)$$

$$B_4 = (\phi_{2,j} - \phi_{1,j}) \;\; \frac{-\gamma^3}{48b^3}(3c_2^2 + 9c_1 c_2 + 3c_1^2)$$

$$B_5 = (\phi_{2,j} - \phi_{1,j}) \;\; \frac{\gamma^3}{16b^3}(c_2 + c_1)$$

$$B_6 = (\phi_{2,j} - \phi_{1,j}) \;\; \frac{-\gamma^3}{48b^3}$$

(3) *(5)* $c_1 = c_2 = 0$

- ✓ $B_{3,ESTAR} = 0$ $B_{3,LSTAR} \neq 0$
- ✓ $B_{3,ESTAR} \neq 0$ $B_{2,LSTAR} = 0$
- ✓ $B_{1,ESTAR} = 0$ $B_{1,LSTAR} \neq 0$

Sequence of Nested Test (Transition Function) $G(s_t)$ Quadratic Logistic Function Logistic Function

$$H_{04} : B_{3,j} = 0$$
$$H_{03} : B_{2,j} = 0 \;\; | B_{3,j} = 0$$
$$H_{02} : B_{1,j} = 0 \;\; | B_{2,j} = B_{3,j} = 0$$

Quadratic Logistic Function H_{04} H_{03} Logistic Function H_{04} H_{03} H_{02} p-value p-value H_{03} Quadratic Logistic Function (Transition Function)

.

MATLAB Vector STAR

```
%This progarm use calculate parametes in Vector LSTAR and Test Hypothesis%
clear;
clc;
tic
%---load data---%
data   = xlsread('ex_iy1999_2004');  %Change i for change maturity
n = 1300
n1 = 3900;
k1 = 1;
n3  = 1300;
k3  = 4;
one = ones(n3,1);
%rearrange date for system ; exre_iy~difslope~exset%
y1      = data(2:end,2);    %---exre_iy---%
y2      = data(2:end,3);    %---difslope----%
y3      = data(2:end,4);    %---exset-----%
y       = [y1;y2;y3;];      %3900x1%
% rearrange date x1%  @ y = exre_iy @
x11    = data(1:end-1,2);   %---lag exre_iy---%
x12    = data(1:end-1,3);   %---difslope---%
x13    = data(1:end-1,4);  %---exset---%
x1     = horzcat(one,x11,x12,x13);                        %1300x4%
x2     = x1;
x3     = x1;
s      = [x11;x11;x11;];                                  %Transition Variable
x_11   = vertcat(x1,zeros((2*n3),k3));                    %3900x4%
x_1    =[x_11 x_11];                                      %3900x8%
x_22   = vertcat(zeros(n3,k3),x2,zeros(n3,k3));           %3900x4%
x_2    =[x_22 x_22];                                      %3900x8%
x_33   = vertcat(zeros((2*n3),k3),x3);                    %3900x4%
x_3    =[x_33 x_33];                                      %3900x8%
x      = horzcat(x_1,x_2,x_3);                            %3900x24%
%---calculate parameters---%
bin=[-.001;.3;-14;-.0007;1.5;-5;-7;.1;-.000002;.0001;.3;.000002;-.002;.01;-2;-.0002;-
.02;137;.05;.03;-.3;-140;.07;.05;38;-.003];
options =optimset('GradObj','off','Hessian','off','Display','iter');
[b,FVAL,EXITFLAG,OUTPUT,GRAD,HESSIAN] = fminunc(@slstarll,bin,options,y,x,s);
var       = inv(HESSIAN);
```

```
tstat      = b./sqrt(diag(var));
pvb        = 1-(tcdf(abs(tstat(1:26)),(n3-18)));
bb         = [bin b tstat pvb];
[q]        = slstar(s,b(6*k3+1),b(6*k3+2));
save output111_6 bin b bb tstat pvb HESSIAN var q EXITFLAG
%----------statistic of first equation-----------------%
yhat1          = ((x1*b(1:4)).*(1-q(1:1300)))+((x1*b(5:8)).*(q(1:1300)));
error1         = y1-yhat1;
abserror1      = abs(errorl);
sumerror1      = error1.'*error1;
MAEl           = mean(abserrorl);
RMSEl          = mean(sumerrorl);
total1         = [y1 yhat1 error1];
%----------statistic of second equation-----------------%
yhat2          = ((x2*b(9:12)).*(1-q(1:1300)))+((x2*b(13:16)).*(q(1:1300)));
error2         = y2-yhat2;
abserror2      = abs(error2);
sumerror2      = error2.'*error2;
MAE2           = mean(abserror2);
RMSE2          = mean(sumerror2);
total2         = [y2 yhat2 error2];
%----------statistic of third equation-----------------%
yhat3          = ((x3*b(17:20)).*(1-q(1:1300)))+((x3*b(21:24)).*(q(1:1300)));
error3         = y3-yhat3;
abserror3      = abs(error3);
sumerror3      = error3.'*error3;
MAE3           = mean(abserror3);
RMSE3          = mean(sumerror3);
total3         = [y3 yhat3 error3];
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Test exists STAR Model
%1. Ho: ai = bi  ; i = 1:4
%2. Ho: c1 = 0
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Test Ho(1); ai = bi  ; i = 1:4
% Wald Test = f(b)'*inv((G(b)*(s'*(inv(x'*x)))*inv(G(b))))*f(b)==>x2(4)
% when  f(b) = RB-q = 0
% G(b) = df(b)/db' = R
% s'*(inv(x'*x))   = Var-Covariance of b
R1       = [eye(4),zeros(4);zeros(4),-eye(4)];
B1       = b(1:8);
fb1      = R1*B1';
```

```
var_cov1 = var(1:8,1:8);
W1       = fb1'*(inv(R1*var_cov1*R1'))*fb1;
pvW1     = 1-(chi2cdf(W1,4));
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Test Ho(2) use T-Test
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%--display parameters--%
disp('Initial value MLE:Parameters  t-stat p-value grad');
disp(bb);
disp('Wald Test Ho_1; ai = bi  ; i = 1:3   p-value');
disp ([W1 pvW1]);
disp('T-Test Ho_2; c1 = 0  p-value');
disp ([tstat(9,1) pvb(9,1)]);
toc
save output111 bin b bb tstat pvb HESSIAN var q EXITFLAG
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [l,g,h]=slstarll(b,y,x,s);
n1 = 3900;
k1 = 1;
n3  = 1300;
k3  = 4;
data   = xlsread('ex_iy1999_2004'); %date~exre_iy~dif_slope~exre_set%    %Change i
for change maturity
y1      = data(2:end,2);           %---exre_iy---%
y2      = data(2:end,3);           %---dif_slope--%
y3      = data(2:end,4);           %---exre_set---%
%---------------------------%
%for sys_2yl%
x11     = data(1:end-1,2);
s       = [x11;x11;x11;];
%---------------------------%
[q1] = slstar(s,b(6*k3+1),b(6*k3+2));
% ik=ones(1,1);
% matq1 = kron(ik',q1);                 %1300x4%
q     = q1(1:1300);
%-----------e1-----------%
dux11     =  x(1:1300,1:4);             %1300x4%
dux12     =  x(1:1300,5:8);             %1300x4%
yhat11    = (dux11*b(1:4)).*(1-q);    %1300x1%
yhat12    = (dux12*b(5:8)).*(q);       %1300x1%
yhat1     =  yhat11 + yhat12;           %1300x1%
e1        =  y1-yhat1;                   %1300x1%
```

```
%-----------e2------------%
dux21     =  x(1301:2600,9:12);       %1300x4%
dux22     =  x(1301:2600,13:16);      %1300x4%
yhat21    = (dux21*b(9:12)).*(1-q);   %1300x1%
yhat22    = (dux22*b(13:16)).*(q);    %1300x1%
yhat2     =  yhat21 + yhat22;         %1300x1%
e2        =  y2- yhat2;               %1300x1%
%-----------e3------------%
dux31     =  x(2601:3900,17:20);      %1300x4%
dux32     =  x(2601:3900,21:24);      %1300x4%
yhat31    = (dux31*b(17:20)).*(1-q);  %1300x1%
yhat32    = (dux32*b(21:24)).*(q);    %1300x1%
yhat3     = yhat21 + yhat22;          %1300x1%
e3        = y3- yhat3;                %1300x1%
e         = [e1;e2;e3];               %3900x1%
%%%%%%%%%%%%%%%%%%%%%%%%%
merror     = horzcat(e1,e2,e3);       %1300x3%
sigm       =  cov(merror);
dsigm      =  det(sigm);
isigm      =  inv(sigm);
iksigm     =  kron(eye(n3),isigm);
l    =  (3*n3/2)*log(2*pi) + (3*n3/2)*log(dsigm) + 0.5*(e'*iksigm* e);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%for Losgitic Function%
function [f,g,h]=slstar(x,c1,c2);
std_st =  std(x);
e      =  exp((-c1*(x-c2))/std_st);
f      =  1./(1+e);
%for Quadratice Logsitic Function%
function [f,g,h]=slstar(x,c1,c2,c3);
std_st =  std(x);
e      =  exp((-c1*(x-c2)*(x-c3))/std_st);
f      =  1./(1+e);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [l,g,h] = sestarll(b,y,x,s);      % Can change for calculate Vector LSTAR
n1 = 3900;
k1 = 1;
n3  = 1300;
k3  = 4;
data   = xlsread('ex_i 0y1999_2004'); %date~exre_2y~dif_slope~exre_set%
y1      = data(2:end,2);    %---exre_iy---%
y2      = data(2:end,3);    %---exf11----%
```

```
y3      = data(2:end,4);    %---exre_set-----%
%----------------------------%
%for sys_2yl%
x11    = data(1:end-1,2);
s      = [x11;x11;x11;];
%----------------------------%
[q1] = sestar(s,b(6*k3+1),b(6*k3+2),b(6*k3+3));
q     = q1(1:1300);
%-----------e1------------%
dux11     =  x(1:1300,1:4); %3900x4%
dux12     =  x(1:1300,5:8);
yhat11    = (dux11*b(1:4)).*(1-q);
yhat12    = (dux12*b(5:8)).*(q);
yhat1     =  yhat11 + yhat12; %
e1        =  y1-yhat1;
%-----------e2------------%
dux21     =  x(1301:2600,9:12); %3900x4%
dux22     =  x(1301:2600,13:16);
yhat21    = (dux21*b(9:12)).*(1-q);
yhat22    = (dux22*b(13:16)).*(q);
yhat2     =  yhat21 + yhat22; %
e2        =  y2- yhat2;
%-----------e3------------%
dux31     =  x(2601:3900,17:20); %3900x4%
dux32     =  x(2601:3900,21:24);
yhat31    = (dux31*b(17:20)).*(1-q);
yhat32    = (dux32*b(21:24)).*(q);
yhat3     = yhat21 + yhat22; %
e3        = y3- yhat3;
e         = [e1;e2;e3]
%%%%%%%%%%%%%%%%%%%%%%%%
merror     =  horzcat(e1,e2,e3);
sigm       =  cov(merror);
dsigm      =  det(sigm);
isigm      =  inv(sigm);
iksigm     =  kron(eye(n3),isigm);
l          =  (3*n3/2)*log(2*pi) + (3*n3/2)*log(dsigm) + 0.5*(e'*iksigm* e);
```

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