Increasing Trends in the Excess Comovements in Commodity Prices

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Motivations and Contributions

Motivations

1. Changes in commodity price correlation have profound implications on
   (a) Commodity producers' hedging strategies
   (b) Speculators' investment strategies
   (c) Countries' energy and food policies
2. Rapid growth of commodity index investment since early 2000s
3. Total value of various commodity index-related instruments purchased by institutional investors had increased from $15 billion to at least $200 billion in mid-2008 (CFTC staff report, 2008)
4. Analyze the effects of financialization process in commodity markets is one of the most important issues

5. Effects of financialization of commodities
   (a) Tang and Xiong (2010, NBER WP)
      i. There was a significant and increasing trend in return correlations of non-energy commodity futures prices with oil after 2004
      ii. Increasing trend is significantly stronger for indexed commodities (listed in the SP-GSCI and DJ-UBS indices) than for off-indexed commodities
   (b) Silvennoinen and Thorp (2010, WP)
      i. Observe a structural break in the conditional correlation processes from the late 1990s
      ii. Correlations between S&P500 returns and returns to the majority commodity futures have increased cases more gradual, and from much earlier in the sample
      iii. High expected stock market volatility (VIX) shifts correlations with S&P500 returns upwards after 2000

6. Weak evidence of excess comovement of commodity prices

   (a) Pindyck and Rotemberg (1990, EJ)

      i. Find the excess comovement (EC) of commodity prices

      ii. Commodity prices have a persist tendency to move together even if the effects of any common macroeconomic shocks are controlled

      iii. 5 out of 21 pairs have significant correlations

      iv. Highest correlation is 0.281 for copper-gold pair

   (b) Deb, Trivedi, and Varangis (1996, JoAE)

      i. Select a more homogeneous sample period of 1974-1992

      ii. Use multivariate GARCH model to treat conditional heteroskedasticity and time-varying correlation in the commodity price data

      iii. Provide little evidence of EC

   (c) Few studies consider the consequence of financialization of commodities on EC

Contributions and Main Results

1. Examine possible regime changes in EC of commodity prices
2. Develop smooth-transition dynamic conditional correlation (STDCC) model
   (a) Capture time-varying conditional correlation
   (b) Allow a regime change in unconditional correlation
3. Regime change seems to be more important than time-varying conditional correlation for EC of commodity prices
4. Find a significant increase in EC in recent years
   (a) EC has been low and stable until 2000
   (b) EC has increased gradually since 2000
5. Increase in EC is not a temporal phenomena due to the recent financial crisis, but a long-run trend

6. Increasing trend in EC is not due to changes in the effects of common macroeconomic variables
7. Correlation dynamics of off-index commodities are quite different from those of price index
8. Indexed commodities are responsible for the increase trends in excess comovement of commodity prices

Methodology

Benchmark model

1. Pindyck and Rotemberg (1990, EJ)
2. $\Delta p_{it} = \alpha_{i0}\Delta x_t + \alpha_{i1}\Delta x_{t-1} + \rho_i \Delta p_{i,t-1} + u_{it}$
   (a) p_{it}: Log of price of commodity i at time t
   (b) x: Vector of macroeconomic variables
   (c) u_{it}: Theoretically uncorrelated error term
   i.e. $\mathrm{Corr}(u_{it}, u_{jt}) = 0, \ \forall i \neq j$
3. Test the null hypothesis of $\mathrm{Corr}(u_{it}, u_{jt}) = 0$
4. PR called significant positive correlations in u excess comovement
5. EC can be overestimated if we ignore the conditional heteroskedasticity and time-varying correlation (Deb, Trivedi, and Varangis, 1996)

Model framework

1. Extend the PR model by accommodating the conditional heteroskedasticity and time-varying correlation
2. $\mathbf{u}_t = (u_{1t}, u_{2t}, \ldots, u_{Mt})' = \mathbf{H}_t^{1/2}\mathbf{v}_t, \quad \mathbf{v}_t \sim \text{iid } N(\mathbf{0}, \mathbf{I}_M)$
3. $\mathbf{H}_t$: Conditional variance-covariance matrix of $\Delta\mathbf{p}_t$
4. $\mathbf{H}_t = \mathbf{D}_t\mathbf{R}_t\mathbf{D}_t$
5. $\mathbf{D}_t = \text{diag}(h_{11,t}, \ldots, h_{MM,t})^{1/2}$
6. $h_{ii,t} = \omega_i + \beta_i h_{ii,t-1} + \alpha_i u_{ii,t-1}^2$
7. $\mathbf{R}_t$: time varying correlation matrix
8. Consider several models for the dynamics of correlation $\mathbf{R}_t$
   (a) PR model: constant correlation ($\mathbf{D}_t = \mathbf{D}$)
   (b) DCC model: stationary model with constant unconditional mean
   (c) STC model: smooth trend in unconditional mean
   (d) STDCC model: trend stationary model with short-run dynamics

Dynamic conditional correlation (DCC) model

1. Proposed by Engle (2002, JBES)
2. Allow heteroskedasticity and time-varying conditional correlation
3. Similar model as that of Deb, Trivedi, and Varangis (1996)
4. Model conditional correlation as GARCH(1,1) model
   (a) $\mathbf{R}_t = \text{diag}(q_{11,t}, \ldots, q_{nn,t})^{-1/2}\mathbf{Q}_t\text{diag}(q_{11,t}, \ldots, q_{nn,t})^{-1/2}$
   (b) $\mathbf{Q}_t = (1-a-b)\bar{\mathbf{Q}} + b\mathbf{Q}_{t-1} + a\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}$
   (c) $\boldsymbol{\varepsilon}_t = \mathbf{D}_t^{-1}\mathbf{u}_t$: standardized disturbance
   (d) $\bar{\mathbf{Q}}$: unconditional variance-covariance (correlation) matrix of $\boldsymbol{\varepsilon}_t$
5. $r_{ij,t} = \frac{(1-a-b)\bar{q}_{ij}+aq_{ij,t-1}+b\varepsilon_{i,t-1}\varepsilon_{j,t-1}}{\sqrt{\left((1-a-b)\bar{q}_{ii}+aq_{ii,t-1}+b\varepsilon^2_{i,t-1}\right)\left((1-a-b)\bar{q}_{jj}+aq_{jj,t-1}+b\varepsilon^2_{j,t-1}\right)}}$
6. Null of no EC: $\bar{q}_{ij} = 0, \ \forall i \neq j$
7. Note that conditional correlation can be nonzero, even no EC

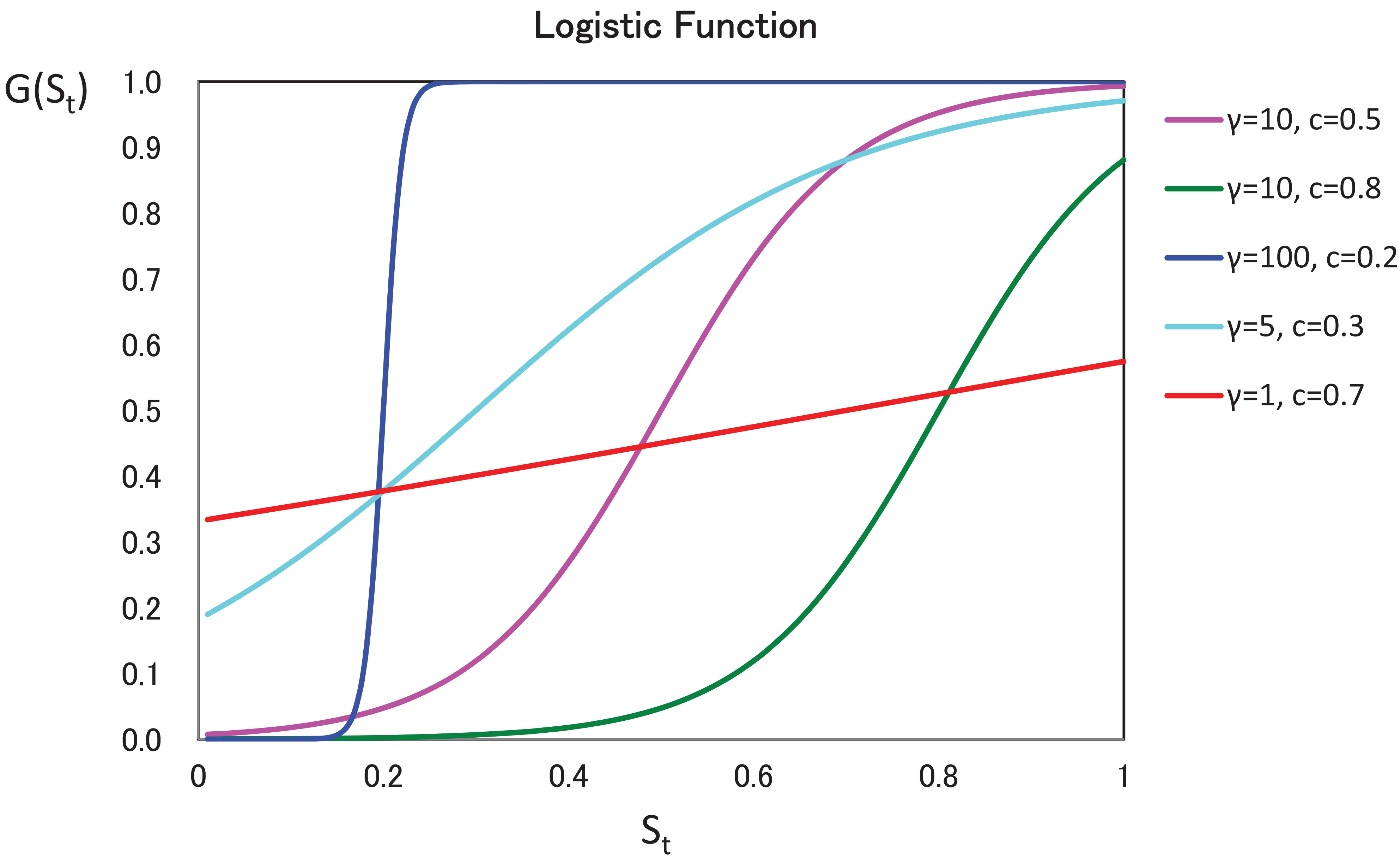
Smooth transition correlation (STC) model

1. Developed by Teräsvirta (1994, JASA) in the AR framework
2. Applied to the time-varying correlation model by Berben and Jansen (2005, JIMF) and Kumar and Okimoto (2011, JBF)
3. $\mathbf{R}_t = (1 - G(s_t; \gamma, c))\mathbf{R}^{(1)} + G(s_t; \gamma, c)\mathbf{R}^{(2)}$
4. One of the regime switching models
   (a) Regime 1: $G = 0 \Longrightarrow \mathbf{R}_t = \mathbf{R}^{(1)}$
   (b) Regime 2: $G = 1 \Longrightarrow \mathbf{R}_t = \mathbf{R}^{(2)}$
5. Regime transition is modeled by a logistic transition function $G(s_t; \gamma, c)$

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

   (a) s_t : Transition variable
   (b) c: Location parameter
   (c) γ: Smoothness parameter

6. Can describe a wide variety of patterns of change
7. Can select the best pattern for the EC of commodity prices
8. Typical choice of a transition variable
   (a) $s_t = \Delta p_{i,t-1}$
      i. $R^{(1)}$: conditional R when $p_{i,t-1}$ decreases largely
      ii. $R^{(2)}$: conditional R when $p_{i,t-1}$ increases largely
   (b) $s_t = t/T$
      i. $R^{(1)}$: unconditional R around the beginning of the sample
      ii. $R^{(2)}$: unconditional R around the end of the sample
9. Adopt $s_t = t/T$ as a transition variable to capture dominant long-run trends (Lin and Teräsvirta, 1994, JoE)
10. Assume $0.01 \leq c \leq 0.99$ to detect the correlation transition within the sample period
11. Null of no EC: $r_{ij}^{(k)} = 0, \ \forall i \neq j, k = 1, 2$


Logistic Function
G(S_t)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.2
0.4
0.6
0.8
1
S_t
γ=10, c=0.5
γ=10, c=0.8
γ=100, c=0.2
γ=5, c=0.3
γ=1, c=0.7

STDCC model

1. Combine DCC and STC models

   (a) $\mathbf{R}_t = \text{diag}(q_{11,t}, \ldots, q_{MM,t})^{-1/2}\mathbf{Q}_t\text{diag}(q_{11,t}, \ldots, q_{MM,t})^{-1/2}$

   (b) $\mathbf{Q}_t = (1 - a - b)\bar{\mathbf{Q}}_t + b\mathbf{Q}_{t-1} + a\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}$

   (c) $\bar{\mathbf{Q}}_t = (1 - G(s_t; \gamma, c))\bar{\mathbf{Q}}^{(1)} + G(s_t; \gamma, c)\bar{\mathbf{Q}}^{(2)}$

2. DCC model can capture the time-varying conditional correlation

3. STC model can allow a smooth regime change in unconditional correlation

4. Null of no EC: $\bar{q}_{ij}^{(k)} = 0, \ \forall i \neq j, k = 1, 2$

Empirical Results

Data (1983:1-2011:7)

1. Indices of Primary Commodity Prices published by the IMF
   (a) Agricultural raw materials: timber, cotton, wool, rubber, hides
   (b) Beverages: coffee, cocoa beans, tea
   (c) Metals: copper, aluminum, iron ore, tin, nickel, zinc, lead, uranium
   (d) Oil: U.K. Brent, Dubai Fateh, West Texas Intermediate
2. Macroeconomic variables obtained from FRED
   (a) Seasonally adjusted CPI
   (b) Seasonally adjusted industrial production
   (c) Seasonally adjusted money supply (M1)
   (d) 3-Month Treasury bill rate
   (e) Trade weighted exchange rate index
   (f) S&P 500

Benchmark model

1. Same analysis as that of Pindyck and Rotemberg (1990)
2. $\Delta p_{it} = \alpha_{i0}\Delta x_t + \alpha_{i1}\Delta x_{t-1} + \rho_i \Delta p_{i,t-1} + u_{it}$
3. 4 out of 6 pairs have significant EC at the 5% significance level
   (a) AGR-BEV: 0.049
   (b) AGR-MET: 0.116**
   (c) AGR-OIL: 0.193***
   (d) BEV-MET: 0.132***
   (e) BEV-OIL: 0.011
   (f) MET-OIL: 0.199***
4. Find weak evidence of EC consistent with PR
5. None of residuals has significant serial correlation at the 5% level
6. Squared residuals have non-negligible serial correlations

DCC model

1. Similar analysis as that of Deb, Trivedi, and Varangis (1996)

2. Regression with GARCH(1,1) disturbance

   (a) $\Delta p_{it} = \sum_{k=0}^{1} \alpha_{ik} \Delta x_{t-k} + \rho_i \Delta p_{i,t-1} + u_{it}$

   (b) $u_{it} = h_{ii,t}^{1/2} v_{it}, \quad v_{it} \sim \text{iid } N(0,1)$

   (c) $h_{ii,t} = \omega_i + \beta_i h_{ii,t-1} + \alpha u_{ii,t-1}^2$

3. GARCH(1,1) model satisfactorily eliminates the serial correlations of squared residuals

4. DCC model

   (a) $\mathbf{D}_t = \text{diag}(h_{11,t}, \ldots, h_{nn,t})^{1/2}$

   (b) $\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t$

   (c) $\mathbf{R}_t = \text{diag}(q_{11,t}, \ldots, q_{nn,t})^{-1/2} \mathbf{Q}_t \text{diag}(q_{11,t}, \ldots, q_{nn,t})^{-1/2}$

   (d) $\mathbf{Q}_t = (1 - a - b)\bar{\mathbf{Q}} + b\mathbf{Q}_{t-1} + a \boldsymbol{\varepsilon}_{t-1} \boldsymbol{\varepsilon}_{t-1}'$

   (e) $\boldsymbol{\varepsilon}_t = \mathbf{D}_t^{-1} \mathbf{u}_t$

5. Evidence of EC becomes slightly weaker consistent with DTV

6. 3 out of 6 pairs have significant EC at the 5% significance level

   (a) AGR-BEV: 0.066

   (b) AGR-MET: 0.094

   (c) AGR-OIL: 0.213***

   (d) BEV-MET: 0.134**

   (e) BEV-OIL: 0.005

   (f) MET-OIL: 0.160***

7. DCC model indicates that conditional correlation fluctuates slightly with insignificant $\hat{a} = 0.004$ and significant $\hat{b} = 0.844$

STC model

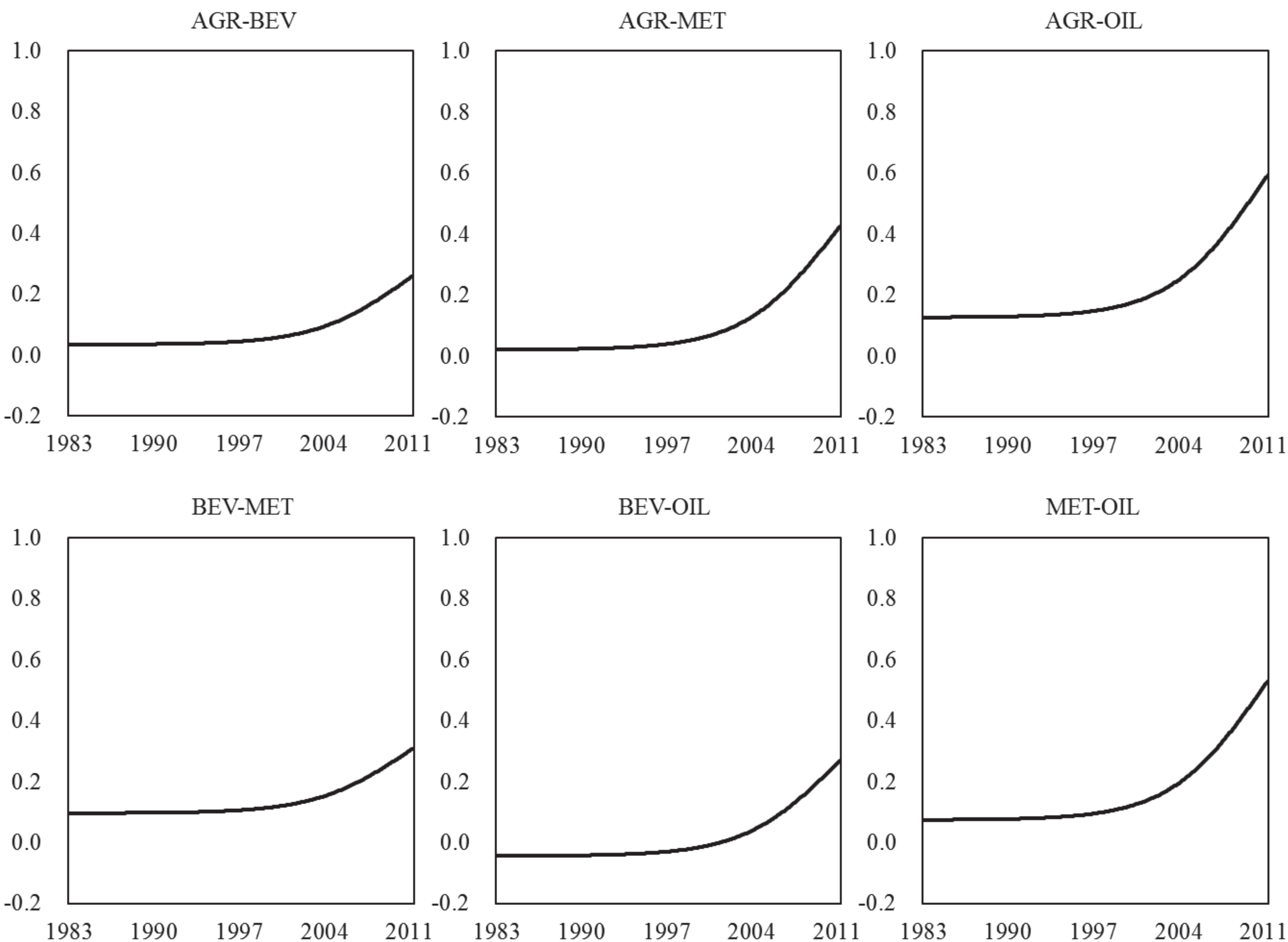
1. Above two models assume unconditional correlation is time-invariant, although DCC model allows time-varying conditional correlation
2. Unconditional correlation may be increasing recently (Tang and Xiong, 2010; Silvennoinen and Thorp, 2010)
3. STC model
   (a) $\mathbf{R}_t = (1 - G(s_t; \gamma, c))\mathbf{R}^{(1)} + G(s_t; \gamma, c)\mathbf{R}^{(2)}$
   (b) $G(s_t; c, \gamma) = \dfrac{1}{1 + \exp(-\gamma(s_t - c))}, \quad \gamma > 0$
   (c) $s_t = t/T$

Table 4: Estimation results of excess comovement for the STC model

		AGR−BEV	AGR−MET	AGR−OIL	BEV−MET	BEV−OIL	MET−OIL
Regime 1	Estimate	0.0334	0.0204	0.1261***	0.0978**	−0.0427	0.0756
	Std. Error	0.0484	0.0511	0.0340	0.0494	0.0458	0.0546
Regime 2	Estimate	0.4372***	0.7462***	0.9647***	0.4800**	0.5176***	0.8931***
	Std. Error	0.1925	0.0789	0.1512	0.0833	0.0901	0.1242
Test of equality	Wald stat	3.4396	51.8552	27.3220	12.9783	19.4645	27.5511
	P−value	0.0637	0.0000	0.0000	0.0003	0.0000	0.0000

4. $\hat{\mathbf{R}}^{(1)}$ suggests that EC is small around the beginning of the sample
5. $\hat{\mathbf{R}}^{(2)}$ indicates that EC has become much stronger toward the end of the sample
6. $H_0 : r_{ij}^{(1)} = r_{ij}^{(2)}$ is rejected for all pairs at the 10% significance level
7. Estimated time series of $\mathbf{R}$ show EC has increased gradually since 2000 with average correlation about 0.398 in July 2011

Figure 1: Dynamics of excess comovement of commodity prices (STC model)



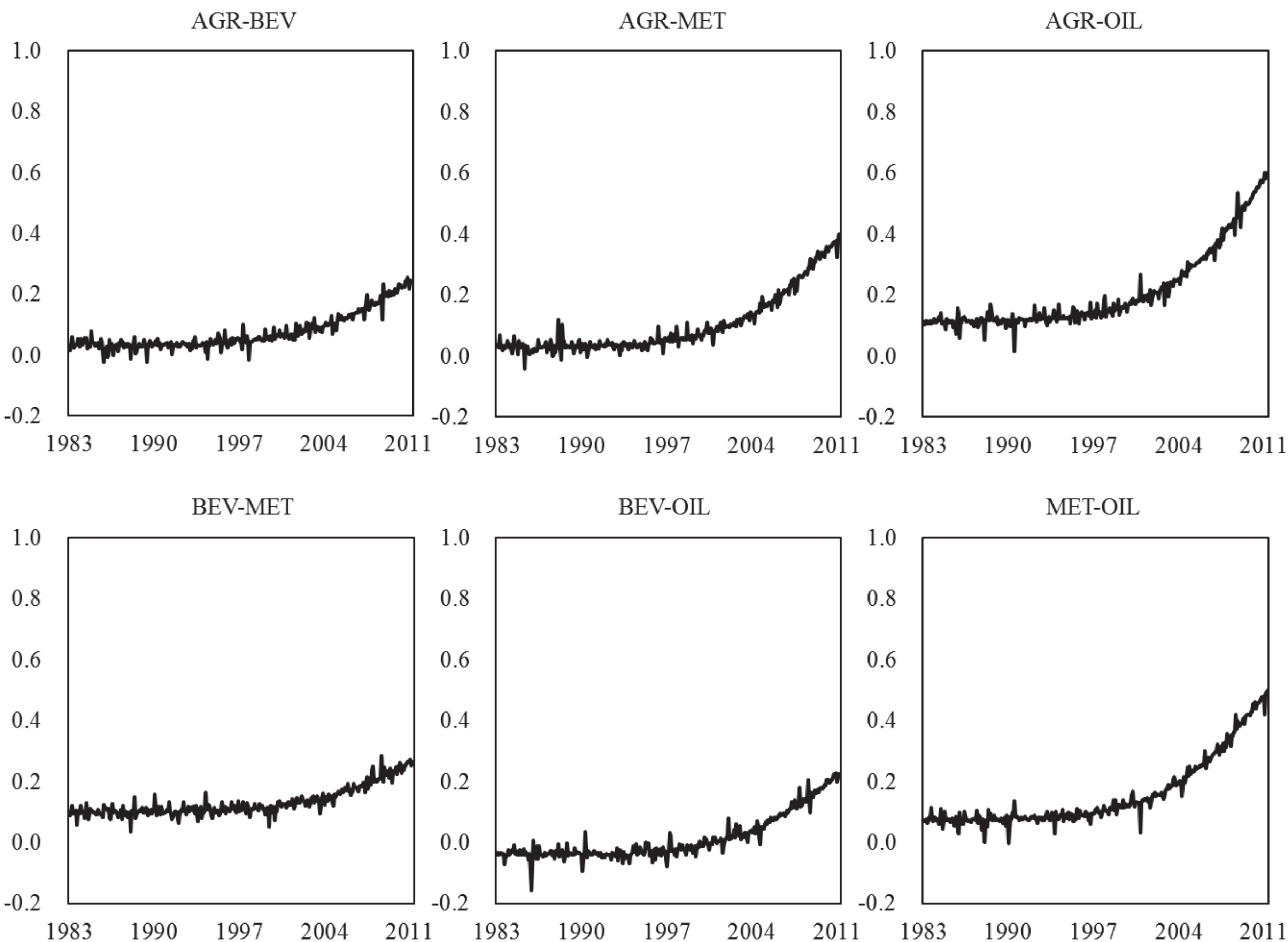
STDCC model

1. STC model does not allow conditional correlation to be time-varying
2. Combine DCC model and STC model
3. STDCC model
   (a) $\mathbf{R}_t = \text{diag}(q_{11,t}, \ldots, q_{nn,t})^{-1/2}\mathbf{Q}_t\text{diag}(q_{11,t}, \ldots, q_{nn,t})^{-1/2}$
   (b) $\mathbf{Q}_t = (1 - a - b)\bar{\mathbf{Q}}_t + b\mathbf{Q}_{t-1} + a\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}$
   (c) $\bar{\mathbf{Q}}_t = (1 - G(s_t; \gamma, c))\bar{\mathbf{Q}}^{(1)} + G(s_t; \gamma, c)\bar{\mathbf{Q}}^{(2)}$
4. Results are essentially the same as those of STC model
5. Neither parameters of DCC are insignificant with $\hat{a} = 0.017$ and $\hat{b} = 0.000$

Table 5: Estimation results of excess comovement for the STDCC model

		AGR−BEV	AGR−MET	AGR−OIL	BEV−MET	BEV−OIL	MET−OIL
Regime 1	Estimate	0.0309	0.0286	0.1116	0.1004	−0.0388	0.0741
	Std. Error	0.1217	0.0968	0.0813	0.0655	0.0967	0.1085
Regime 2	Estimate	0.4157***	0.6722***	0.9732***	0.3992***	0.4415***	0.8245***
	Std. Error	0.1362	0.1864	0.3901	0.1502	0.1017	0.3488
Test of equality	Wald stat	2.9897	6.2469	4.2997	2.7483	7.9954	2.8039
	P−value	0.0838	0.0124	0.0381	0.0974	0.0047	0.0940

Figure 2: Dynamics of excess comovement of commodity prices (STDCC model)



6. $\hat{\mathbf{R}}^{(1)}$ suggests that EC is small around the beginning of the sample
7. $\hat{\mathbf{R}}^{(2)}$ indicates that EC has become much stronger toward the end of the sample
8. $H_0 : r_{ij}^{(1)} = r_{ij}^{(2)}$ is rejected for all pairs at the 10% significance level
9. Estimated time series of $\mathbf{R}$ show EC has increased gradually since 2000 with average correlation about 0.369 in July 2011

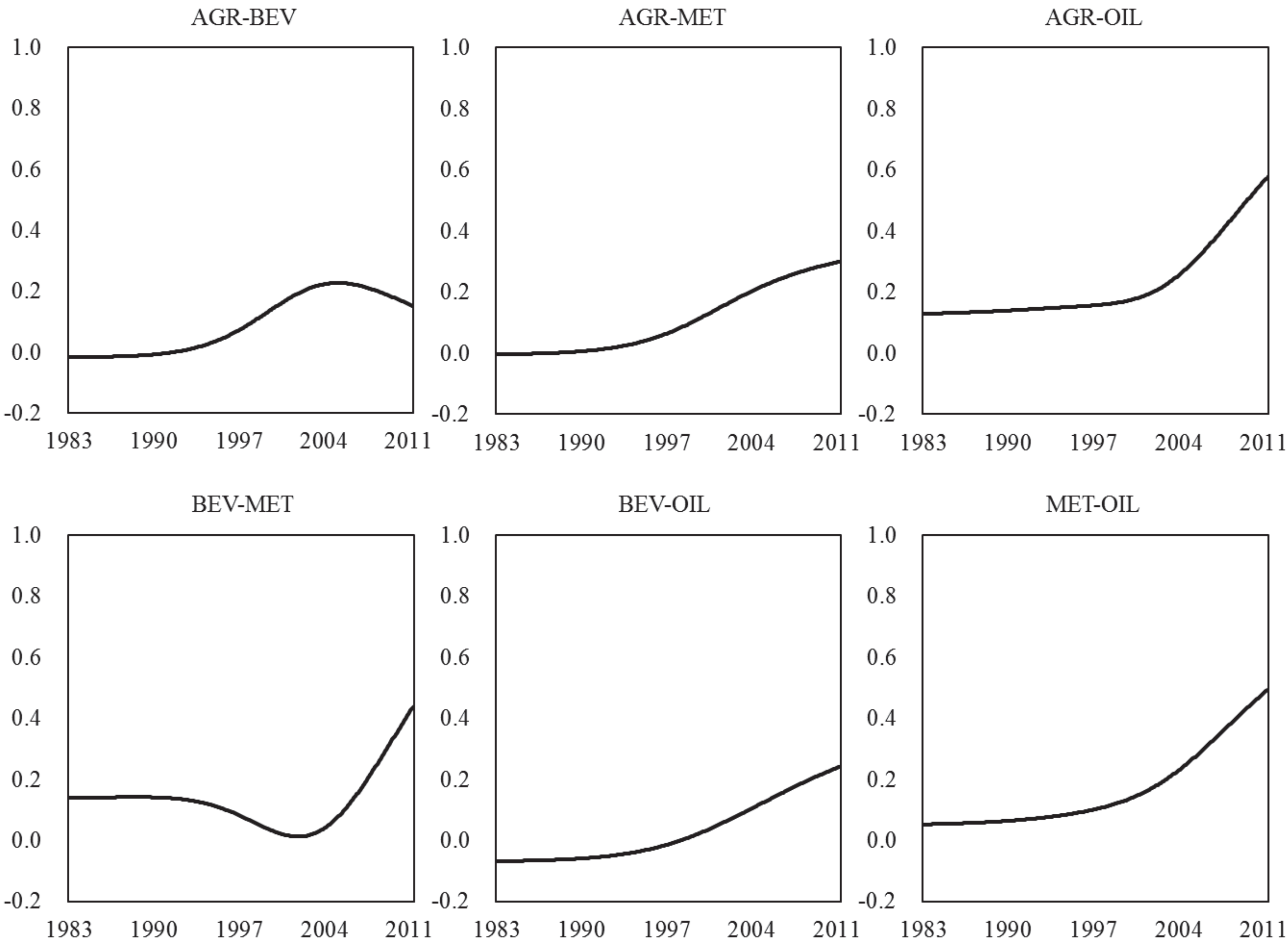
Three state STC model

1. Two-state STC model allows only a monotonic transition with time
2. Correlations among commodity returns might become higher around the financial crisis
3. Increasing trends could be an artifact of a temporal increase at the financial crisis
4. Three state model can allow non-monotonic changes in correlations

$$\begin{aligned}\mathbf{R}_t = & \; \mathbf{R}^{(1)} + G_1(s_t;\gamma_1,c_1)(\mathbf{R}^{(2)} - \mathbf{R}^{(1)}) \\ & + G_2(s_t;\gamma_2,c_2)(\mathbf{R}^{(3)} - \mathbf{R}^{(2)})\end{aligned}$$

5. Assume $0.01 \leq c_1 < c_2 \leq 0.99$ to detect the correlation transition within the sample period
6. $\mathbf{R}_t$ changes smoothly from $\mathbf{R}^{(1)}$ via $\mathbf{R}^{(2)}$ to $\mathbf{R}^{(3)}$ with time

Figure 3: Dynamics of excess comovement of commodity prices (3state STC model)



7. Estimated time series of $\mathbf{R}$ indicates that the increasing trends in excess comovement is not an artifact produced by the financial crisis
8. Improvement of the fit by the extra regime is marginal
9. Usual information criteria support the two state model over the three state model

STR model

1. STC model assumes that the effects of common macroeconomic variables are constant
2. Ignorance of changes in the effects of common macroeconomic factors might produce the increase in excess comovement
3. To examine the possibility, consider the ST regression (STR) model:

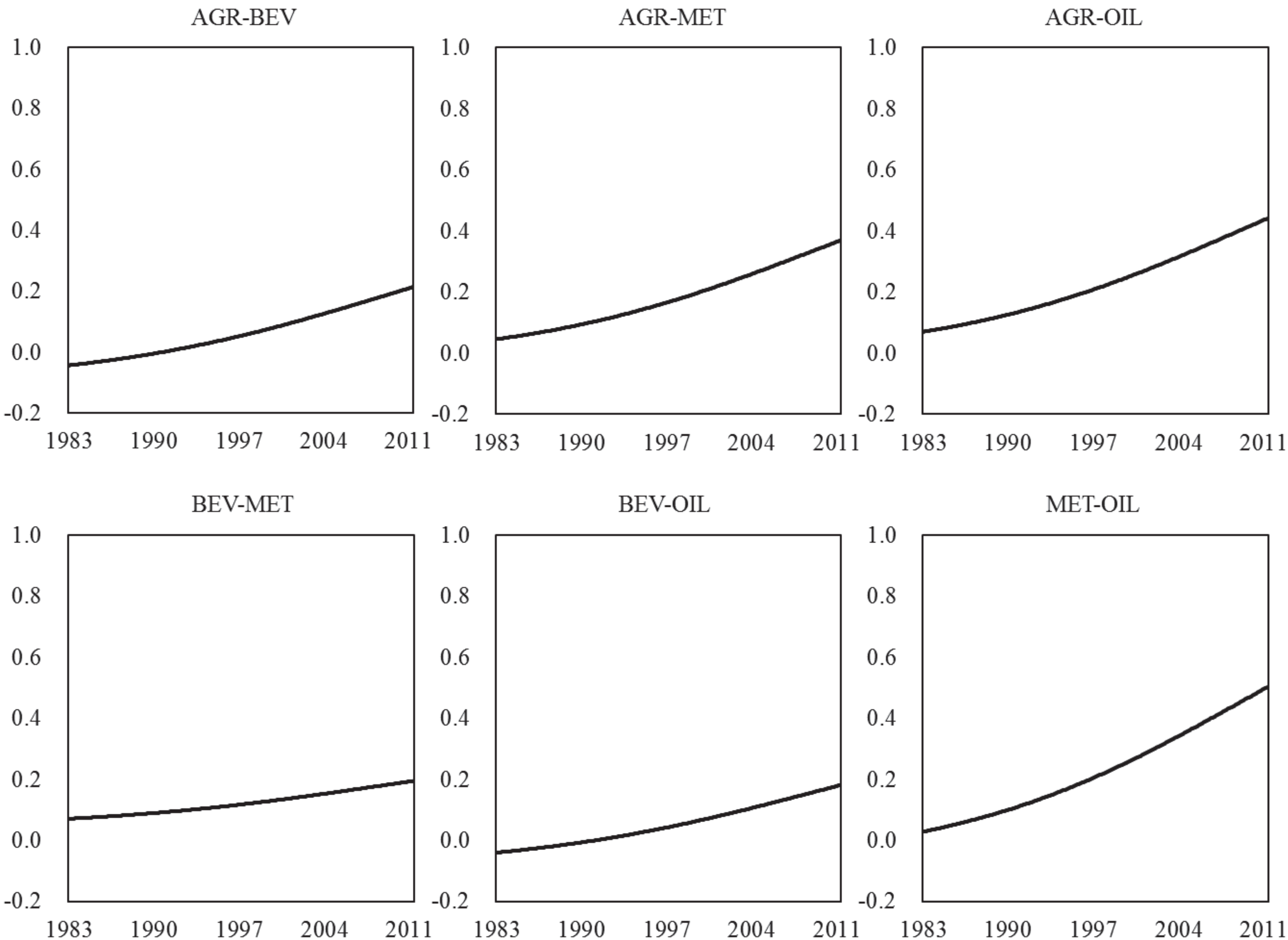
$$\begin{aligned}\Delta p_{it} = & (1 - G(s_t; \gamma, c))(\alpha_i^{(1)} \Delta x_t + \rho_{i1}^{(1)} \Delta p_{i,t-1} + \sigma^{(1)} \varepsilon_{it}) \\ & + G(s_t; \gamma, c)(\alpha_i^{(2)} \Delta x_t + \rho_i^{(2)} \Delta p_{i,t-1} + \sigma^{(2)} \varepsilon_{it})\end{aligned}$$

4. Estimate the two-state STC model using the standardized residuals $\hat{\varepsilon}_t$ from the STR model
5. No significant excess comovement in regime 1, but the significant excess comovement in regime 2 with significant increases
6. Correlation dynamics become more linear but increasing trends are still quiet similar

Table 6: Estimation results of excess comovement for the residuals from the STR model

		AGR-BEV	AGR-MET	AGR-OIL	BEV-MET	BEV-OIL	MET-OIL
Regime 1	Estimate	-0.1023	-0.0279	-0.0144	0.0443	-0.0882	-0.0771
	Std. Error	0.0691	0.0723	0.0906	0.0751	0.0816	0.1103
Regime 2	Estimate	0.4706***	0.6930***	0.8156***	0.3212***	0.4041***	0.9819***
	Std. Error	0.1190	0.1387	0.1966	0.1025	0.1162	0.2328
Test of equality	Wald stat	12.8188	16.2639	9.6229	3.1250	7.9782	11.3053
	P-value	0.0003	0.0001	0.0019	0.0771	0.0047	0.0008

Figure 4: Dynamics of excess comovement of commodity prices (STR residuals)



Off-index commodities

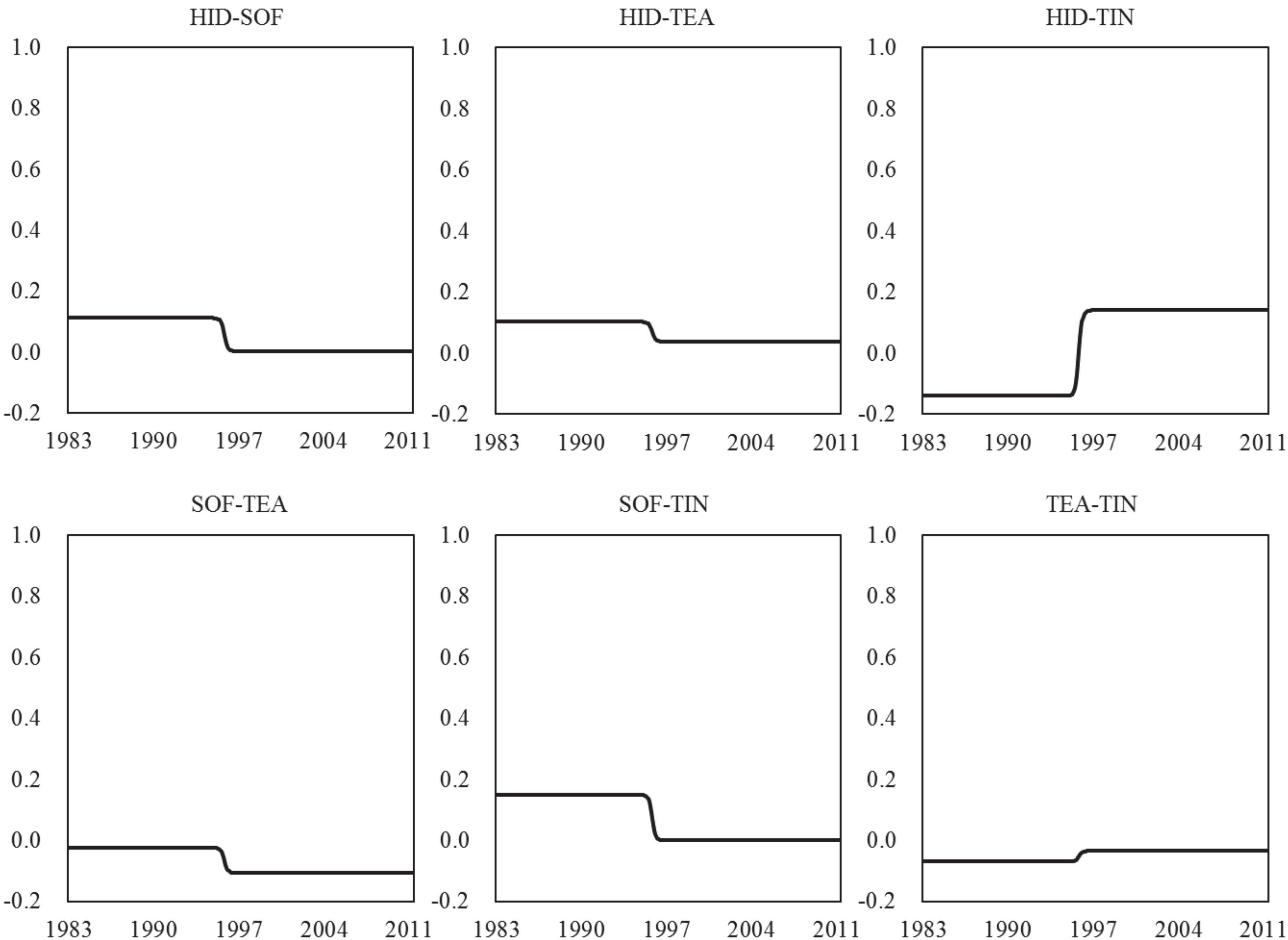
1. IMF commodity price indexes contain several off-index commodities
   (a) Hides (Agricultural materials, 2.6%)
   (b) Timber (Agricultural materials, 3.4%)
      i. Hardwood (1.2%)
      ii. Softwood (2.2%)
   (c) Rubber (Agricultural materials, 0.5%)
   (d) Wool (Agricultural materials, 0.5%)
      i. Fine (0.2%)
      ii. Coarse (0.3%)
   (e) Tea (Beverages, 0.3%)
   (f) Iron ore (Metal, 1.3%)
   (g) Tin (Metal, 0.2%)
   (h) Uranium (Metal, 0.5%)
2. Monthly price data of iron ore is available from only 2009

3. Uranium price does not change often for the first several years
4. Conduct the same analysis using Hides, Softwood, Tea and Tin
5. $\hat{\mathbf{R}}^{(1)}$ suggests that EC is small around the beginning of the sample
6. $\hat{\mathbf{R}}^{(2)}$ indicates that EC is still small around the end of the sample
7. $H_0 : r_{ij}^{(1)} = r_{ij}^{(2)}$ is not rejected at the 10% significance level for all pairs except hides-tin pair
8. Estimated time series of $\mathbf{R}$ show that EC has remained at low levels throughout the sample
9. Results are qualitatively similar if the rubber or coarse wool is used instead of softwood or hides
10. Correlation dynamics of off-index commodities are quite different

Table 7: Estimation results of excess comovement for off-index commodities

		HID−SOF	HID−TEA	HID−TIN	SOF−TEA	SOF−TIN	TEA−TIN
Regime 1	Estimate	0.1112	0.1021	−0.1401*	−0.0234	0.1509*	−0.0679
	Std. Error	0.0815	0.0771	0.0784	0.0852	0.0828	0.0806
Regime 2	Estimate	0.0027	0.0380	0.1398*	−0.1052	0.0022	−0.0331
	Std. Error	0.0727	0.0758	0.0722	0.0710	0.0704	0.0733
Test of equality	Wald stat	0.9842	0.3550	6.9105	0.5261	1.8681	0.1015
	P−value	0.3212	0.5513	0.0086	0.4682	0.1717	0.7500

Figure 5: Dynamics of excess comovement of off-index commodity prices (STC model)



Conclusion

1. Examine possible regime changes in excess comovement of commodity prices
2. Develop smooth-transition dynamic conditional correlation (STDCC) model
   (a) Capture time-varying conditional correlation
   (b) Allow a regime change in unconditional correlation
3. Find little EC until 2000
4. Provide new evidence of gradual significant increase in EC since 2000
5. Increase in EC is not an artifact due to the recent financial crisis nor changes in the effects of common macroeconomic variables
6. Indexed commodities are responsible for the increase trends in excess comovement of commodity prices

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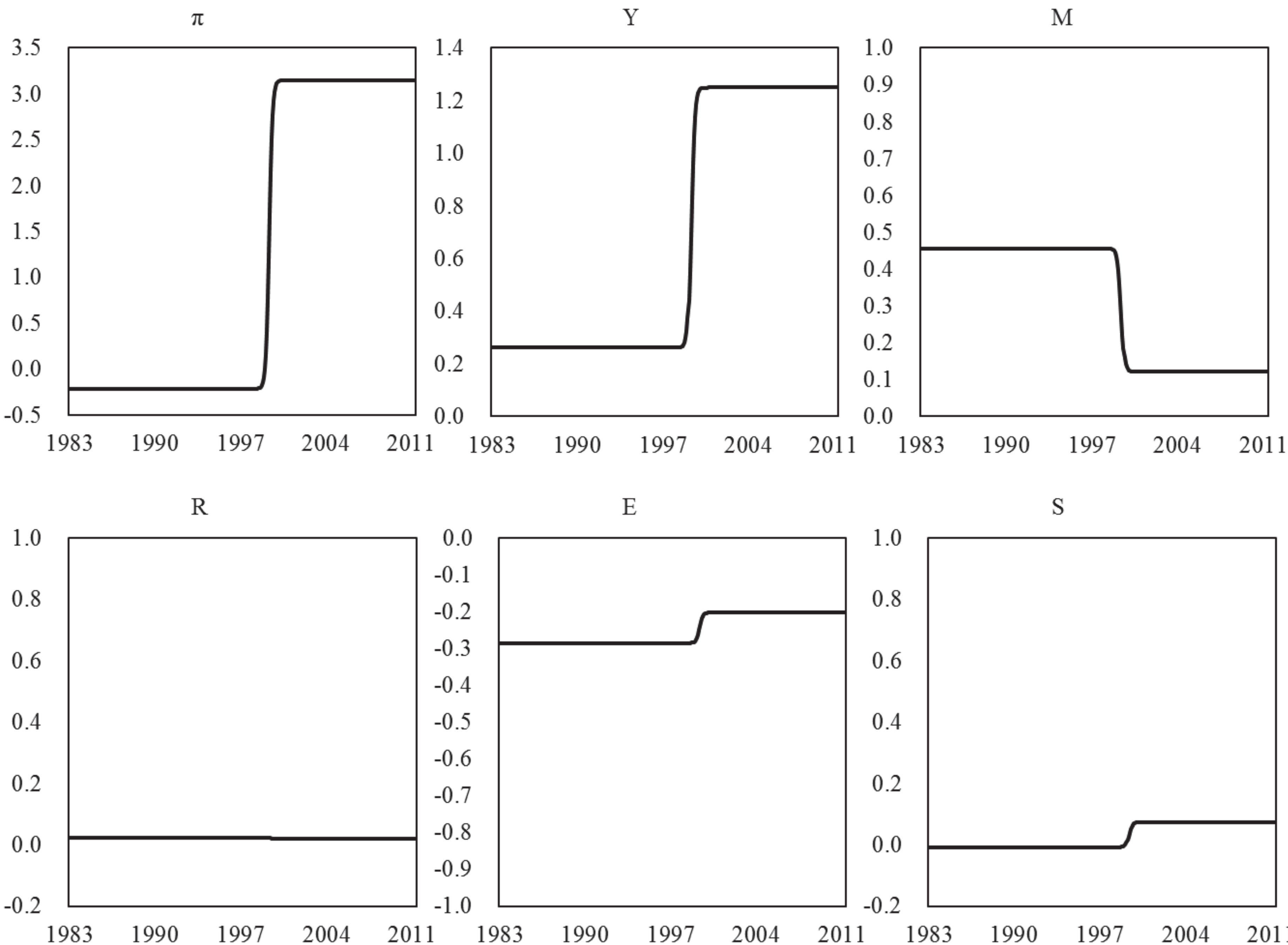
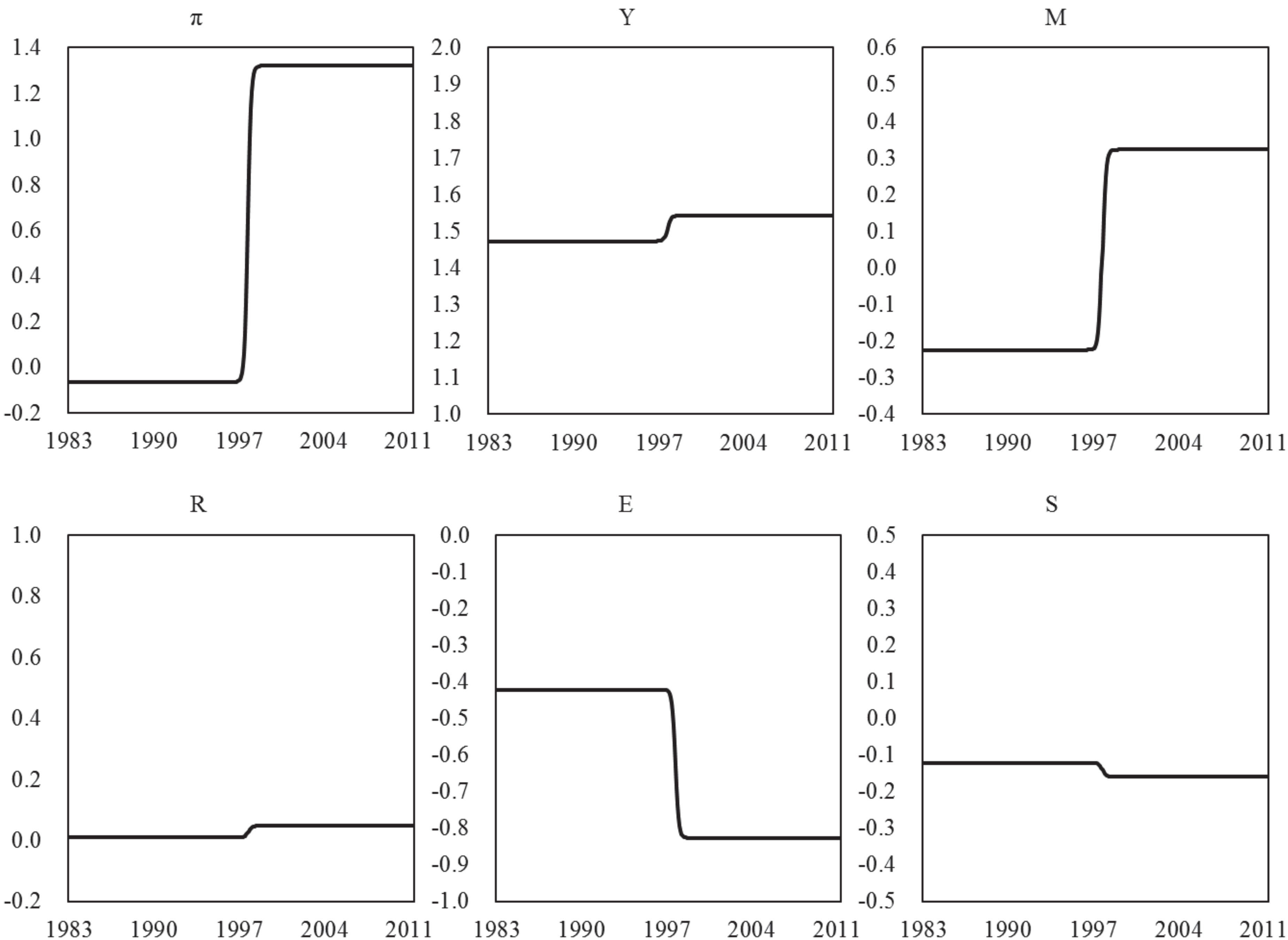
Figure : Dynamics of coefficients of STR model (Agriculture)



Figure：Dynamics of coefficients of STR model (Beverage)



Figure：Dynamics of coefficients of STR model (Metal)

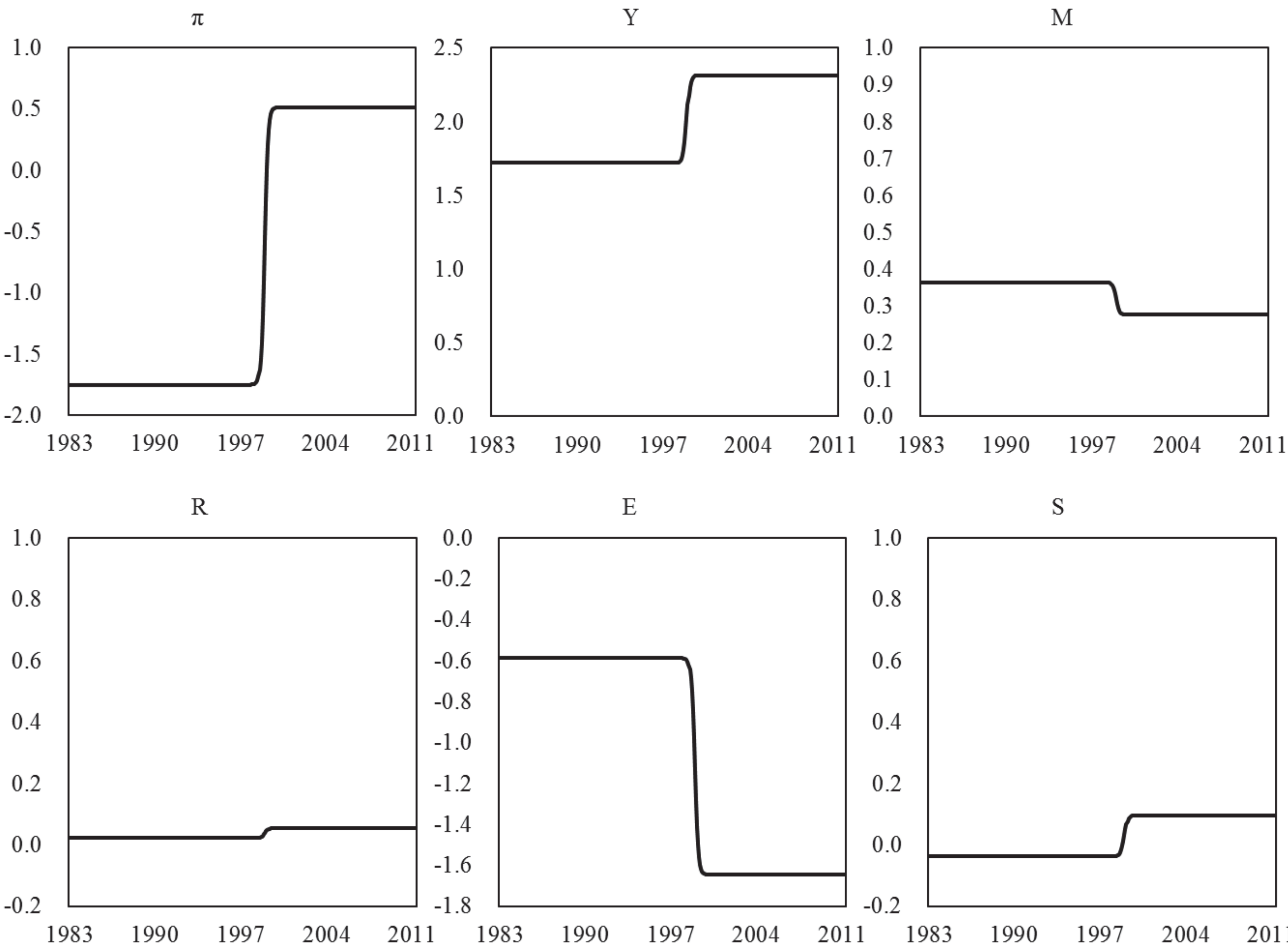


Figure : Dynamics of coefficients of STR model (Oil)