Analyzing the condition of Japanese electricity cost linkages by fossil fuel sources after the Fukushima disaster

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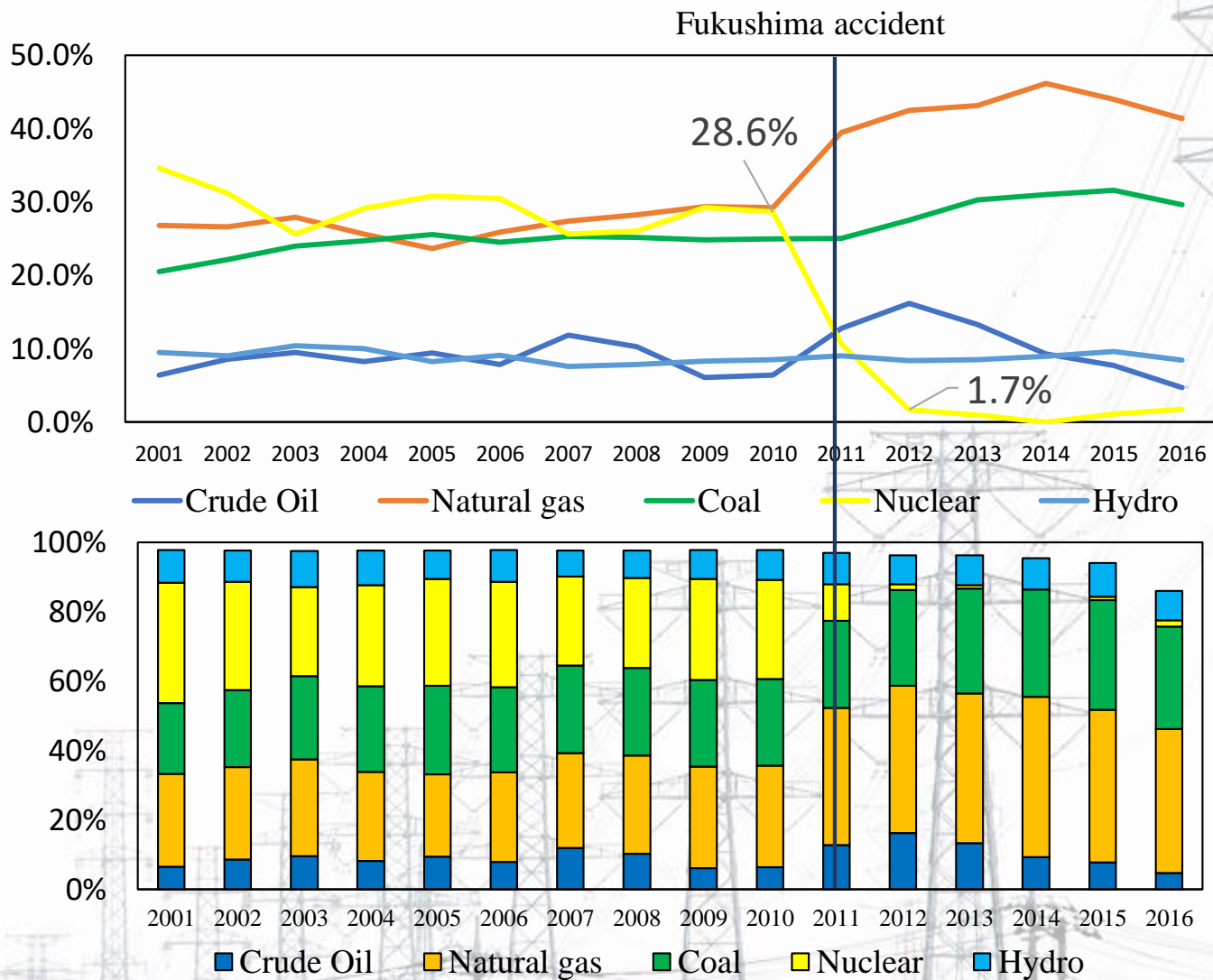
Gross power generation mix of Japan

Research questions

To investigate the followings before and after the Fukushima accident.

1. The dynamics of the cost spreads among the three major fossil fuels (crude oil, natural gas, and coal).

2. The cointegration relationship (i.e., a systematic co-movement) between the costs of electricity generation from crude oil, natural gas, and coal.

Relevant studies

- Studies on changes in energy mix after the accident
  - Hayashi and Hughes (2013)
    - The Japanese government will increase the use of fossil fuels for electricity after the accident
  - Vivoda (2012)
    - In the short to medium term, the shares of imported oil, coal, and liquefied natural gas (LNG) would expand to compensate for the reduction in nuclear power generation.
- Studies on market integration among fossil fuels
  - Batten et al. (2017)
  - Brigida (2014)
  - Bachmeier and Griffin (2006)

Data
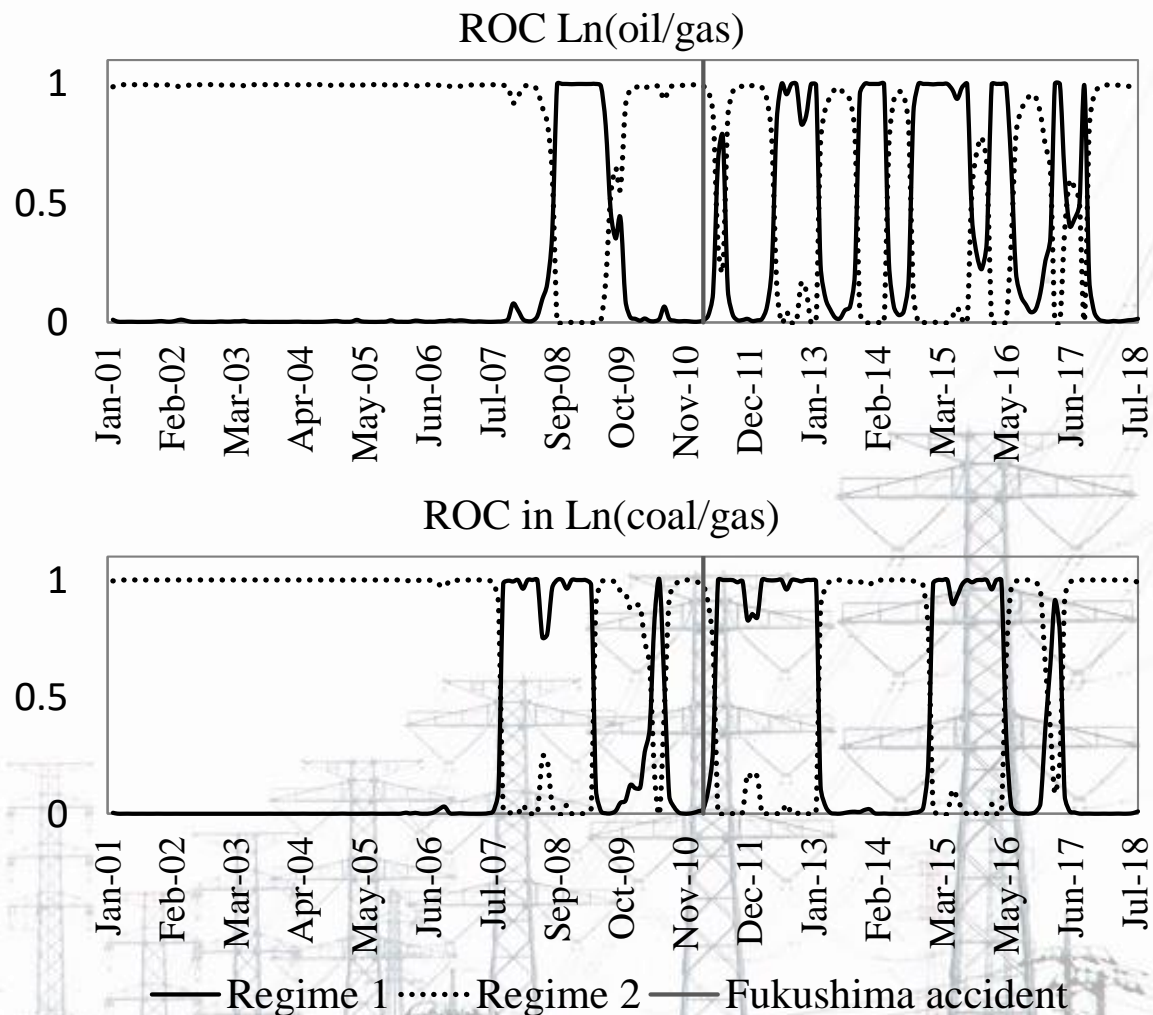
Natural log

Source: pps-net.org

Markov switching smoothed regime probabilities (oil-gas and coal-gas cost spreads)

ROC Ln(oil/gas)

ROC in Ln(coal/gas)

——Regime 1 ·······Regime 2 ——Fukushima accident

Markov switching smoothed regime probabilities (oil-coal cost spread)

ROC Ln(oil/coal)
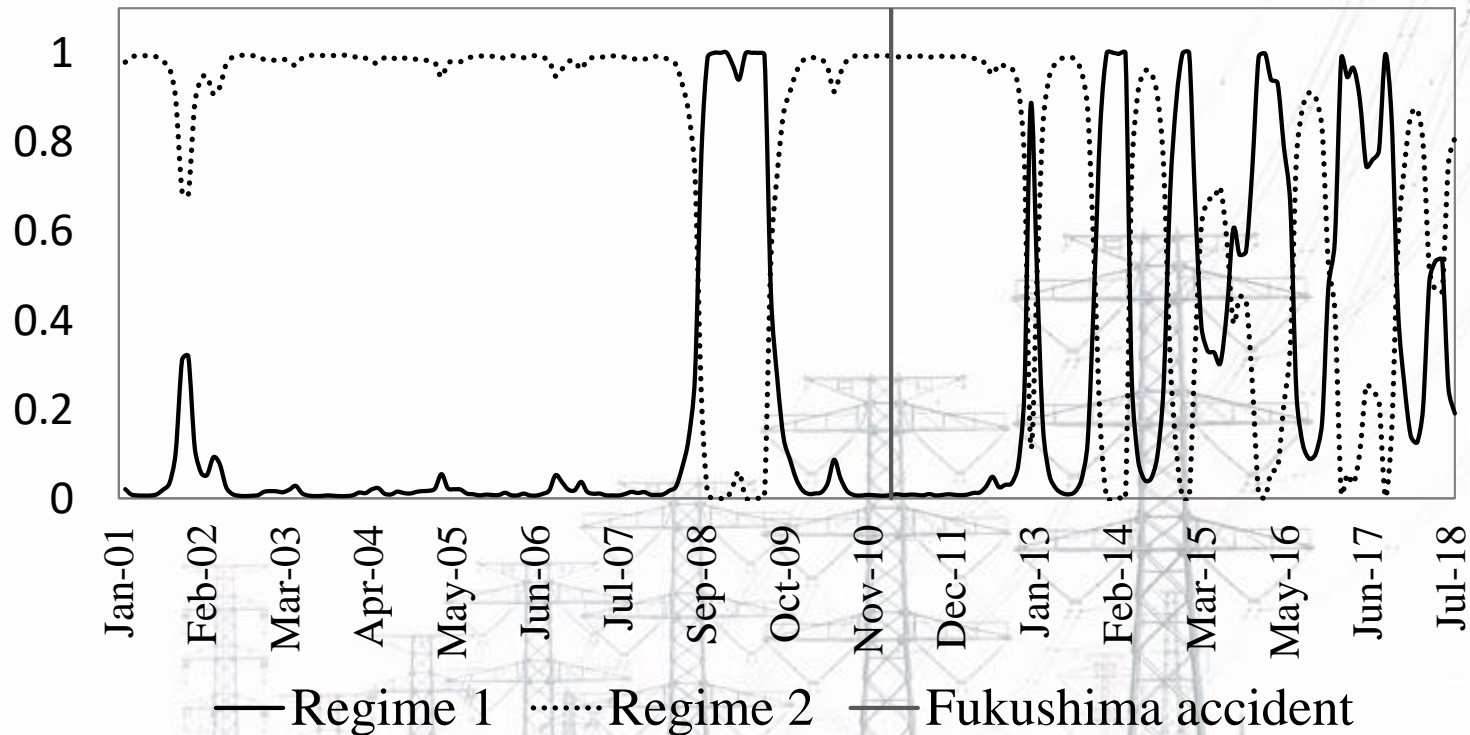
Regime classification and its expected duration

Regime	ROC Ln(oil/gas)			ROC Ln(oil/coal)			ROC Ln(coal/gas)		
	Start	End	Expected duration	Start	End	Expected duration	Start	End	Expected duration
Regime 1	Sep-08	Aug-09	6.57	Sep-08	Aug-09	6.01	Oct-07	May-09	9.99
	Jun-11	Aug-11		Jan-13	Feb-13		May-10	Aug-10	
	Jun-12	Mar-13		Dec-13	May-14		Jun-11	Mar-13	
	Nov-13	May-14		Nov-14	Apr-15		Feb-15	May-16	
	Oct-14	Oct-15		Sep-15	Jul-16		Feb-17	May-17	
	Feb-16	Jul-16		Jan-17	Nov-17				
	Mar-17	Jun-17		May-18	Jul-18				
	Sep-17	Oct-17							
Regime 2	Feb-01	Sep-08	19.20	Feb-01	Sep-08	19.92	Feb-01	Oct-07	26.13
	Aug-09	Jun-11		Aug-09	Jan-13		May-09	May-10	
	Aug-11	Jun-12		Feb-13	Dec-13		Aug-10	Jun-11	
	Mar-13	Nov-13		May-14	Nov-14		Mar-13	Feb-15	
	May-14	Oct-14		Apr-15	Sep-15		May-16	Feb-17	
	Oct-15	Feb-16		Jul-16	Jan-17		May-17	na	
	Jul-16	Mar-17		Nov-17	May-18				
	Jun-17	Sep-17		Jul-18	na				
	Oct-17	na							

Note: Start represents the date when regime probabilities start to exceed 0.5 and end is the date when probabilities turn below

Implications from the MRSM

1 → Switching from one regime to another → Become more frequent after the Fukushima accident

2 → Time of the switching for oil-gas and coal-gas cost ratios → The timing of the switching was consistent with the accident

Stationarity tests

Before the accident (2001:1-2011:2)

	Level				First differences			
	ADF	PP	KPSS	IO	ADF	PP	KPSS	IO
Crude oil	-2.486	-2.325	0.181 **	-2.366	-6.199 ***	-4.318 ***	0.042	-6.374 ***
Natural gas	-2.558	-2.348	0.122 *	-1.489	-4.826 ***	-7.294 ***	0.052	-7.519 ***
Coal	-2.327	-2.084	0.131 *	-1.190	-7.486 ***	-7.486 ***	0.054	-8.198 ***

After the accident (2011:3-2018:8)

	Level				First differences			
	ADF	PP	KPSS	IO	ADF	PP	KPSS	IO
Crude oil	-2.702	-2.352	0.144 *	-3.846	-7.668 ***	-7.031 ***	0.080	-7.010 ***
Natural gas	-2.382	-2.050	0.181 **	-3.762	-4.770 ***	-4.871 ***	0.134 *	-4.862 ***
Coal	-3.300 *	-2.319	0.137 *	-1.614	-5.131 ***	-8.199 ***	0.039	-9.551 ***

ADF, PP, and KPSS unit root tests include both constant and trend, and IO unit root test only includes a constant. ***, **, and * denotes significance at 1%, 5%, and 10% respectively.

Johansen tests

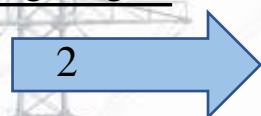Before the accident (2001:1-2011:2)

Variables	H_0: rank=r	Trace test	Max test	Lag length
Oil and Gas	r=0	19.555 *	15.866 *	4
	r<=1	3.689	3.689	
Oil and Coal	r=0	21.961 **	17.015 **	2
	r<=1	4.946	4.946	
Coal and Gas	r=0	20.378 **	16.728 **	2
	r<=1	3.650	3.650	

➜ Cointegrated

After the accident (2011:3-2018:8)

Variables	H_0: rank=r	Trace test	Max test	Lag length
Oil and Gas	r=0	30.960 ***	28.582 ***	2
	r<=1	2.378	2.378	
Oil and Coal	r=0	7.962	6.070	1
	r<=1	1.892	1.892	
Coal and Gas	r=0	8.130	7.257	2
	r<=1	0.873	0.873	
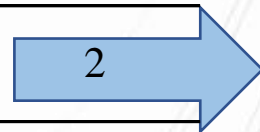
➜ Cointegrated
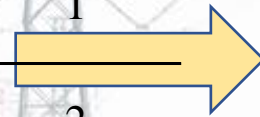
➜ **Not** Cointegrated

Recursive trace test

Before Mar. 2011　　　After Mar. 2011

Oil and Gas　　Oil and Coal　　Coal and Gas　　5% crtical value
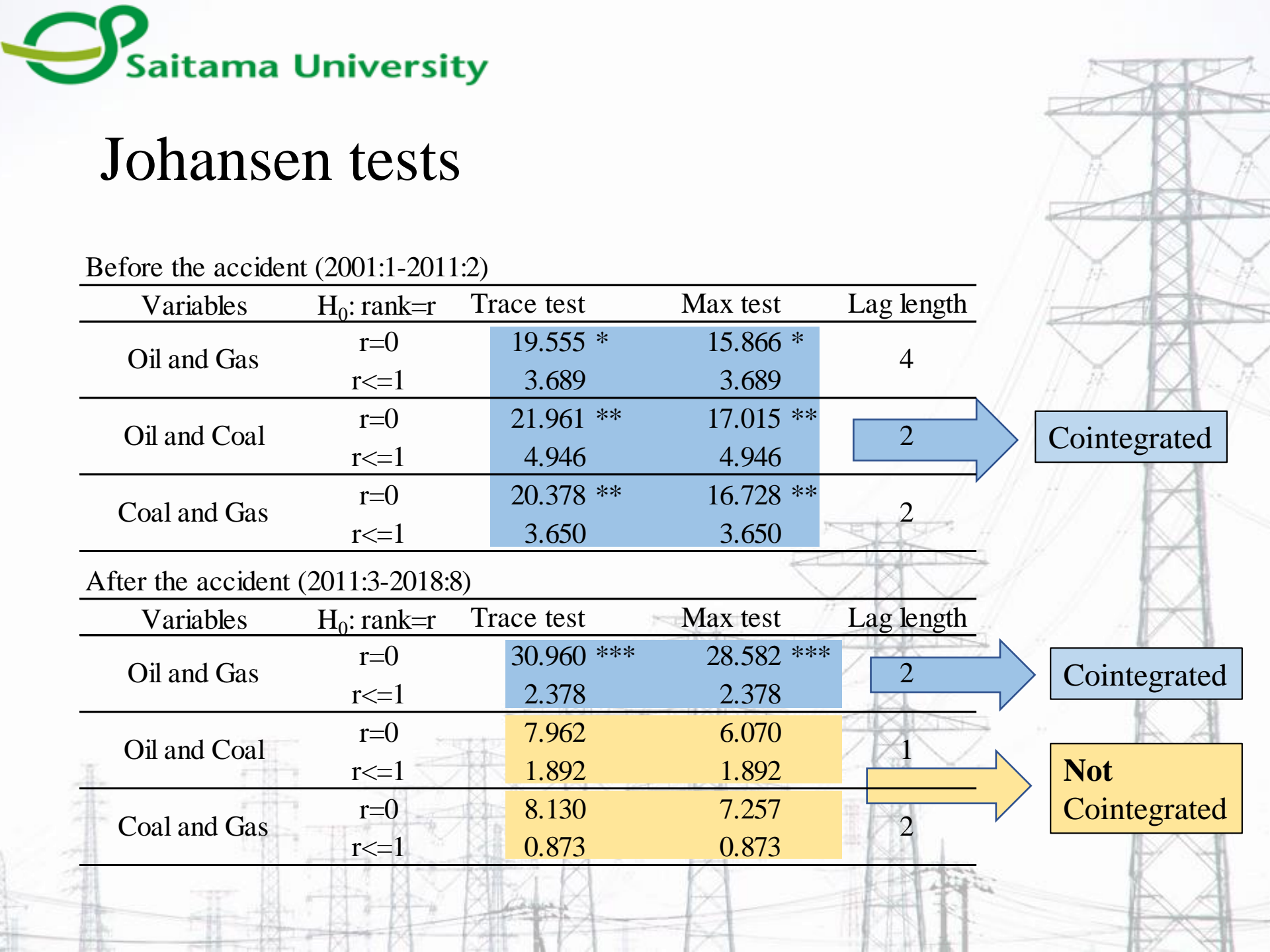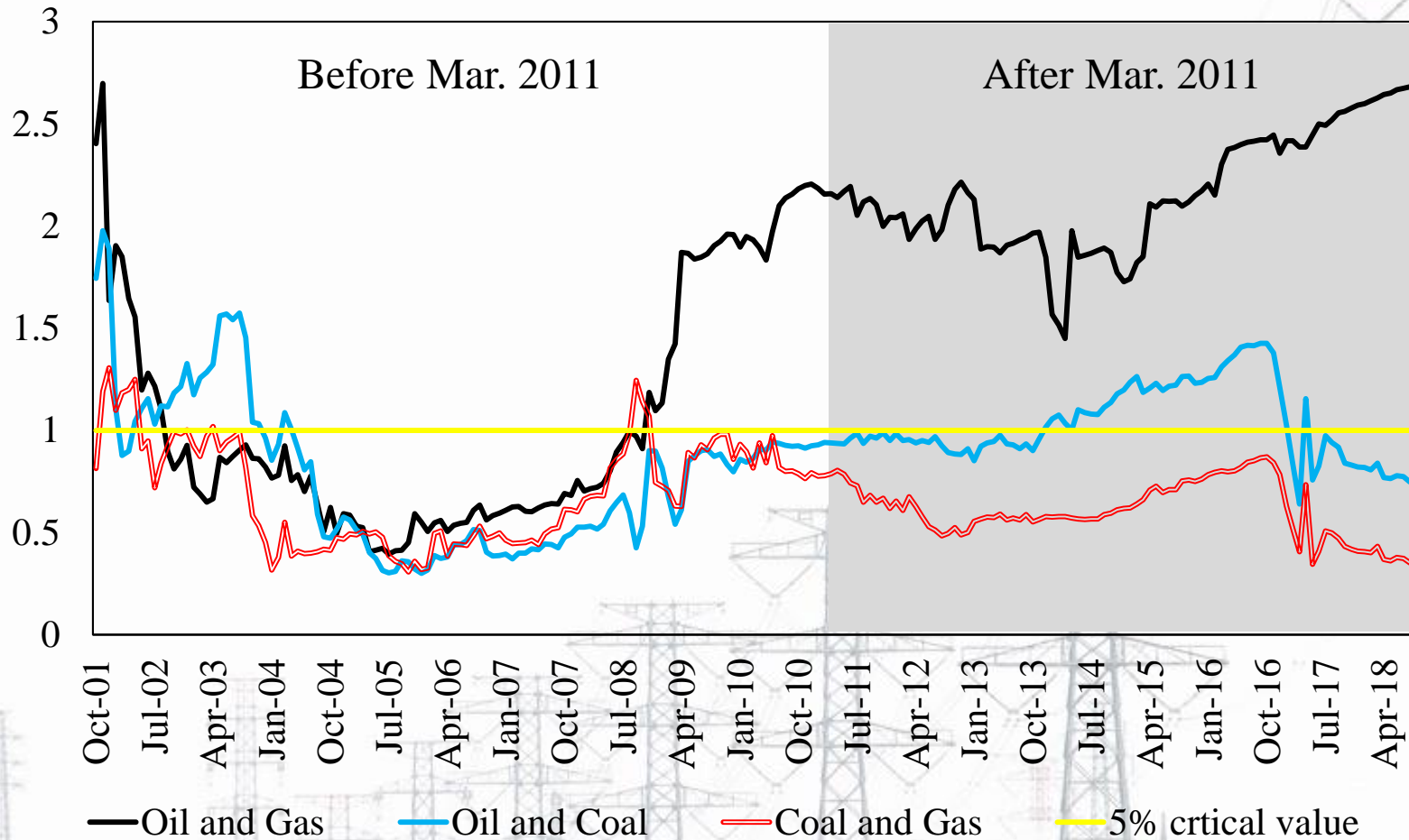
Bierens-Martins tests

Before the accident (2001:1-2011:2)

Variables	Chebyshev Time Polynomials	Test statistic	P-value
Oil and Gas	m=1	7.93 **	0.019
	m=2	24.53 ***	0.000
	m=4	37.81 ***	0.000
Oil and Coal	m=1	12.49 ***	0.002
	m=2	25.96 ***	0.000
	m=4	32.08 ***	0.000
Coal and Gas	m=1	3.10	0.212
	m=2	5.68	0.224
	m=4	14.12 **	0.028

Time variant cointegration relationships

After the accident (2011:3-2018:8)

Variables	Chebyshev Time Polynomials	Test statistic	P-value
Oil and Gas	m=1	1.47	0.481
	m=2	13.54 ***	0.009
	m=4	13.57 **	0.035

Null hypothesis: Time invariant cointegration

Time invariant cointegration relationships

Implications from the cointegration tests

1

| Oil-gas relationship | → | Become stronger after the accident | → | Increased linkages to global market |

2

| Coal-oil and coal-gas relationships | → | Linkages disappeared after the accident | → | Reflecting Japanese energy policy to promote LNG after the accident |

3

| Increase in the stability of oil-gas relationship after the accident | → | Oil-gas relationship became more persistent due to increased dependency on these fuels |

Conclusions

After the Fukushima accident

1. The dynamics of the fossil fuel cost relationships seemed to have changed.

   - Suggests that a flexible energy policy is more effective than fixed one.

2. Cost relationship between oil and gas became stronger while those between coal-oil and coal-gas linkages dissipated.

   - This implies that the Japanese electricity became more reliant on oil and gas after the accident.

Thank you for your attention!

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