The Causal Relationship in North American Energy Production

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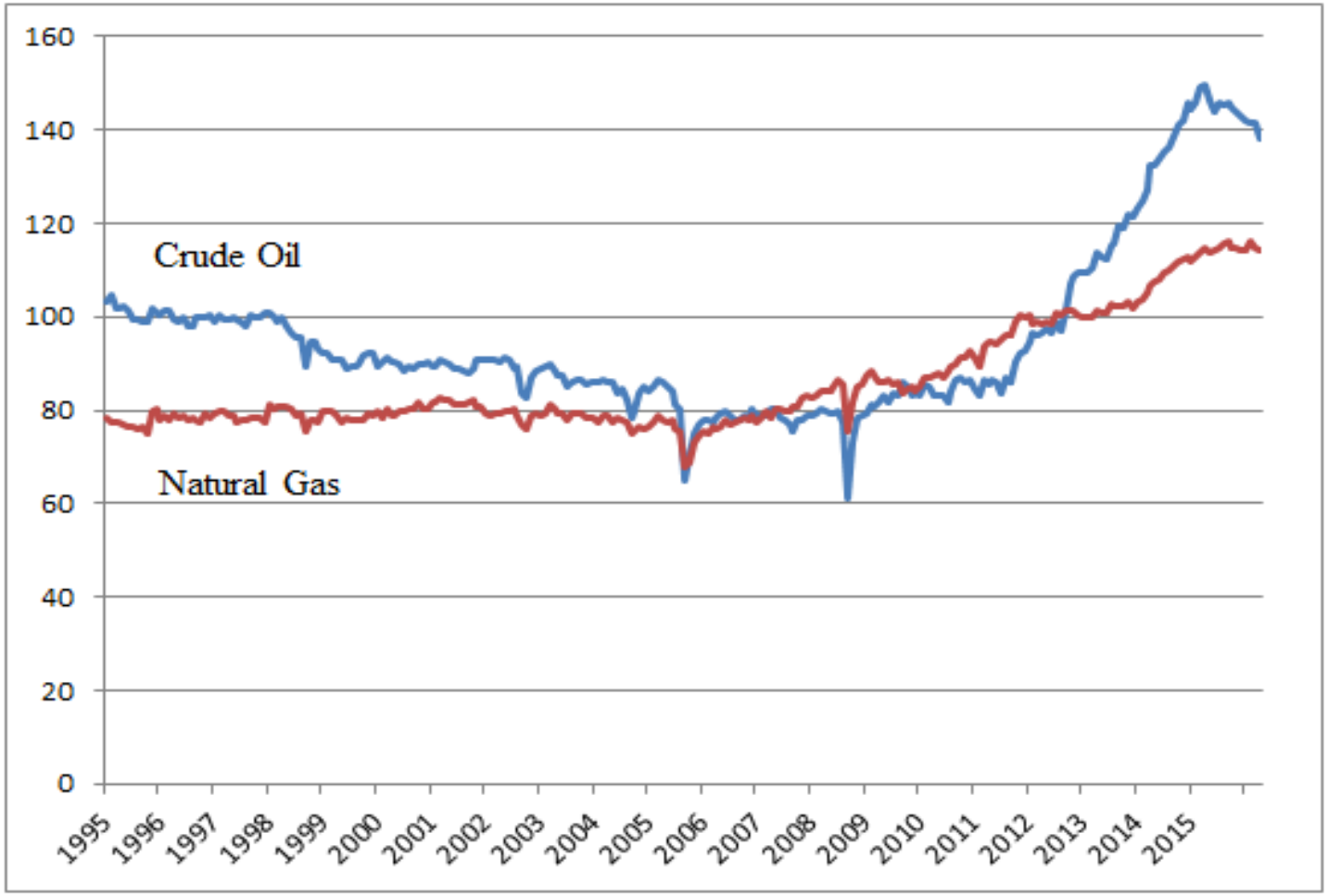
Introduction

- Significant changes have occurred in North American energy markets over the past decade
  - Particularly in the case of the United States –> Shale revolution
  - Since 2002, the US has seen a 12-fold increase in the production of natural gas from shale
  - In 2013 US production of shale oil (3.5 mb/d) was 3 times higher than 2010.
  - Four decade oil ban on oil exports recently overturned In US

US Primary Energy Production



Note: The data was obtained from the Federal Reserve Economic Database, and is Industrial Production: Mining: Crude oil and Industrial Production: Mining: Natural gas

Canadian Impact?

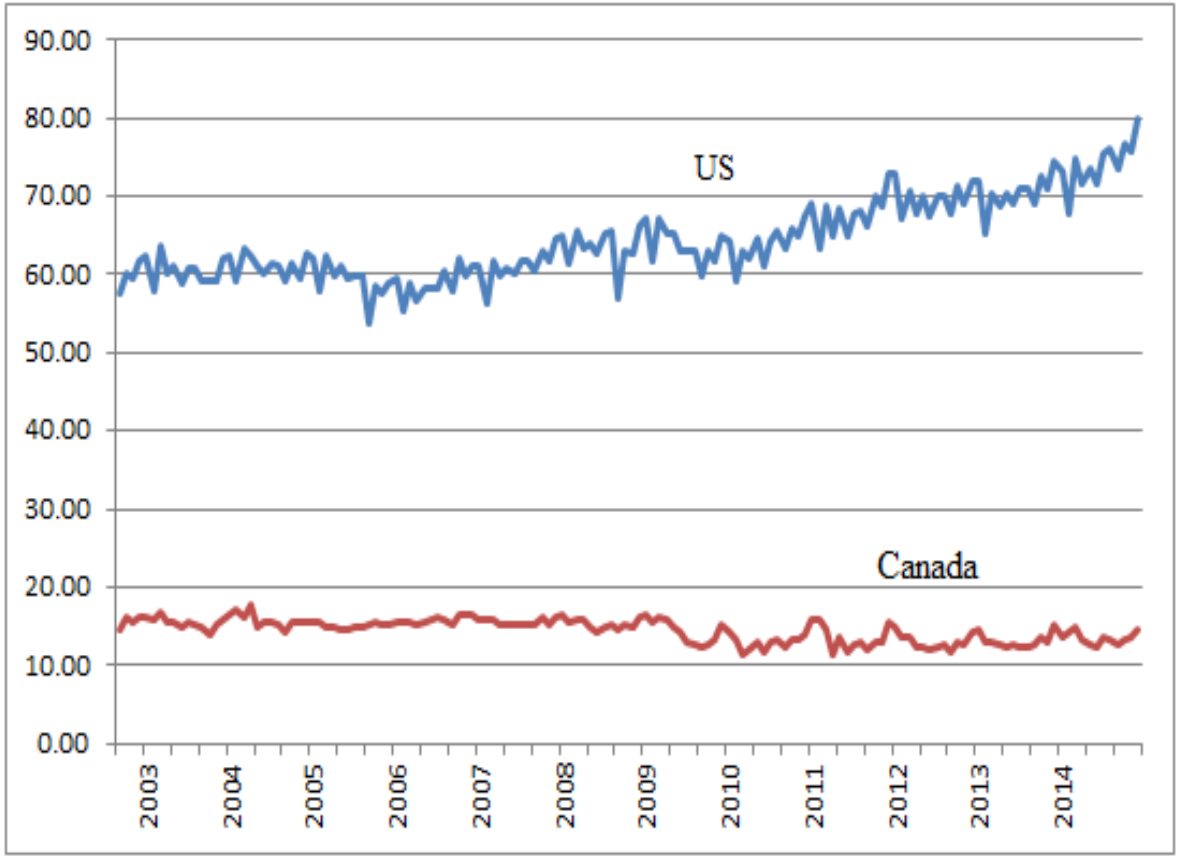
What is the nature of the impact on the Canadian market?

- Similar geologic formation of comparable composition.
  - Bakken on the Border
- Spread of new techniques / technology
- Vast majority of energy commodities are exported to the US
  - US market now flush with crude oil and natural gas
- Hughes (2013) discusses the high decline rates in shale wells

North American Energy Production

CRUDE OIL

Natural Gas



Econometric Methodology

- Simple Model

$$OP_{l,t} = \alpha_0 + \alpha_1 OP_{l,t-1} + \alpha_2 OP_{k,t-1} + e_{1,t}$$

$$GP_{l,t} = \beta_0 + \beta_1 GP_{l,t-1} + \beta_2 GP_{k,t-1} + e_{2,t}$$

- Complete Model

$$OP_{l,t} = \alpha_0 + \alpha_1 OP_{l,t-1} + \alpha_2 OP_{k,t-1} + \alpha_3 WTIP_t + \alpha_4 FX_t + e_{1,t}$$

$$GP_{l,t} = \beta_0 + \beta_1 GP_{l,t-1} + \beta_2 GP_{k,t-1} + \beta_3 HHP_t + \beta_4 Storage + \beta_5 CDD_t + \beta_6 HDD_t + e_{2,t}$$

Data

- Monthly production data; 2002 through early 2015

Table: Summary Statistics

	Natural Gas		Crude Oil	
	U.S.A.	CDA	U.S.A.	CDA
Beginning	September-02	September-02	October-02	October-02
End	August-15	August-15	October-15	October-15
Mean	50.62	14.45	8,199.1	2,855.0
Variance	44.30	1.97	3,379,580.2	169,896.6
STd. Dev	6.66	1.41	1,838.4	412.2
Coefficient of Variation	13.1%	9.7%	22.4%	14.4%
Skew	0.57	-0.31	1.32	0.7
Kurt	-0.66	-0.92	0.57	-0.2
JB Test Normality	11.19	8.01	47.97	14.39
p - value	0.00	0.02	0.00	0.00
n	156	156	157	157

Results

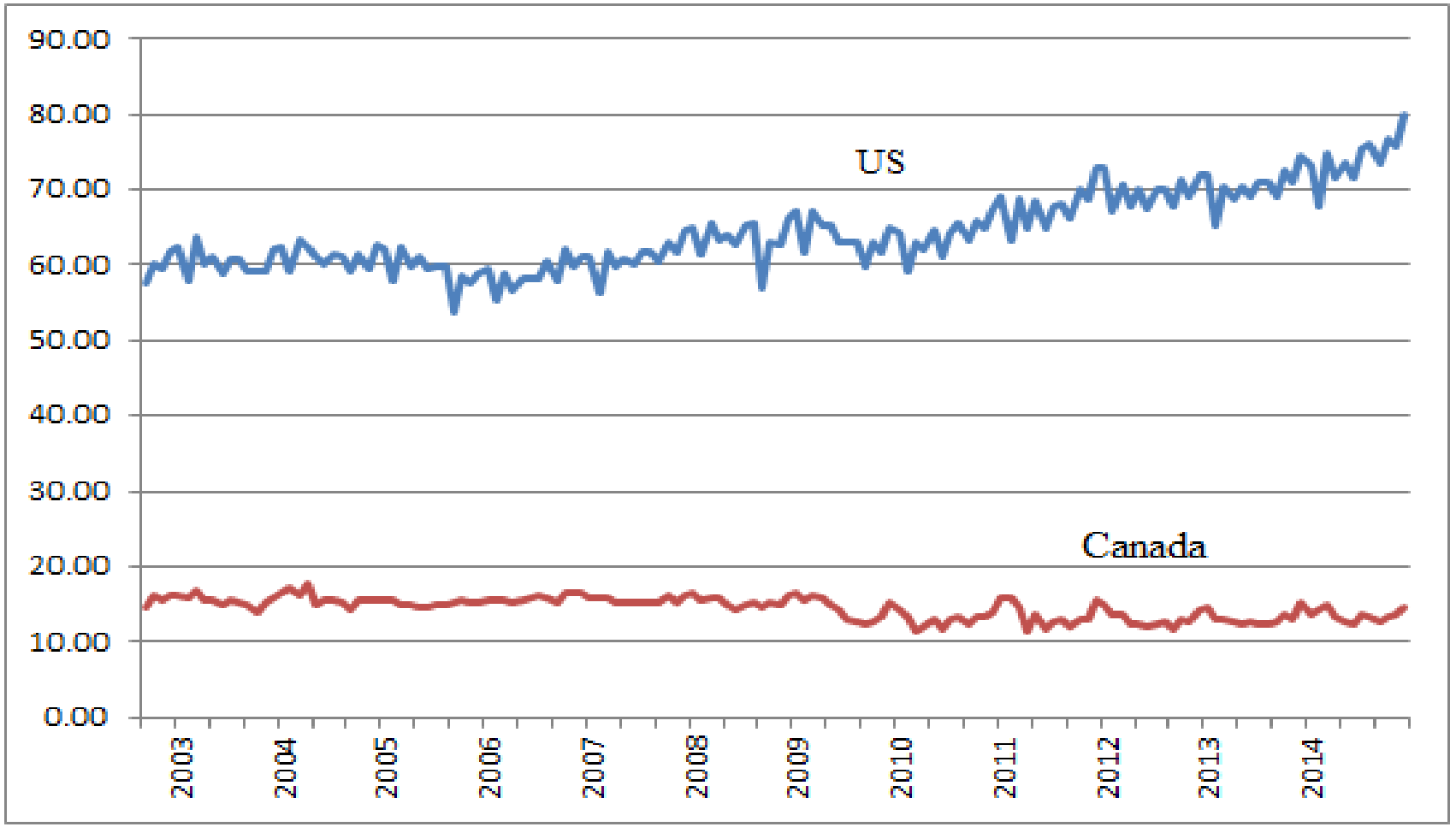
- Augmented Dickey – Fuller Test
  - US and Canadian crude oil and natural gas production is nonstationary in levels
  - All series are stationary in first differences

- Cointegration tests
  - Johansen Test indicates cointegrating relationship for crude oil
  - Less clear for Natural Gas
  - Park test supportive of cointegration

Vector Error correction model

- Results:
  - Speed of adjustment term is significant across models
  - Consistently higher for Canadian production than for American production
  - Coefficient is positive in the final two natural gas models.

Natural Gas Production



Granger Causality Tests

#	Model	χ^2 stat	p -value	Direction
1	$OP_{US} = f(OP_{CDA})$	30.502	0.000	Bi-directional
2	$OP_{CDA} = f(OP_{US})$	52.991	0.000	
3	$OP_{US} = f(OP_{CDA}, WTIP, FX)$	50.343	0.000	Bi-directional
4	$OP_{CDA} = f(OP_{US}, WTIP, FX)$	18.005	0.000	
5	$GP_{US} = f(GP_{CDA})$	7.153	0.007	USA →
6	$GP_{CDA} = f(GP_{US})$	0.541	0.462	Canada
7	$GP_{US} = f(GP_{CDA}, Storage, HDD, CDD)$	13.031	0.001	USA →
8	$GP_{CDA} = f(GP_{US}, Storage, HDD, CDD)$	2.766	0.251	Canada

Note: $\chi 2$ represents the test statistic in the Granger Causality test.

Implications & Conclusions

- Park's CCR results support the notion that the production variables are cointegrated.
- Granger Causality tests with the CCR terms included provide same results as above except
  - Presence of bi-directional causal relationship in production of natural gas (simple model)
- North American is a highly integrated energy market
  - Long-run relationship among crude oil and natural gas production