Asymmetric Reactions of the U.S. Natural Gas Market and Economic Activity

Bao H. Nguyen[*] Tatsuyoshi Okimoto[*,†]

[*]Crawford School of Public Policy, Australian National University

[†]Research Institute of Economy, Trade and Industry (RIETI)

December 8th, 2017

Central Bank of Sri Lanka
10th International Research Conference

Outline of the talk

Motivation 1

1. Crude oil and natural gas are two of the most important energy commodities
2. The empirical literature has shown contrasting results on the relationship between the price of natural gas and crude oil:
    1. Crude oil prices have a key role in shaping natural gas prices
       Pindyck (2004); Brown and Yücel (2008); Zamani (2016); Jadidzadeh and Serletis (2017)
    2. Weak or no connection between the two prices
       Serletis and Rangel-Ruiz (2004); Bachmeier and Griffin (2006); Ramberg and Parsons (2012).
3. Instructive to provide new empirical evidence on the relationship between crude oil and natural gas prices

Motivation 2

1. A huge number of literature examines the effects of oil price shocks on real economy
   Kilian (2009); Hamilton (2011); Baumeister and Peersman (2013); Kilian and Murphy (2014); Baumeister and Kilian (2016a,b)
2. Few studies investigate the role of natural gas price shocks on the US economy
3. Interesting to assess the impacts of natural gas price shocks on the US economy

Motivation 3

1. Many previous studies rely on linear models
2. Recent growing literature suggests the existence of nonlinearities
   1. Regime-switching in the relationship between the price of natural gas and crude oil
      Brigida (2014); Atil et al. (2014)
   2. Asymmetric reactions of energy price shocks and the economy
      Hamilton (2003, 2011); Baumeister and Peersman (2013)
3. Important to consider possible asymmetries in the reactions of the U.S. natural gas market and economic activity

Addressed questions

1. Are the reactions of the U.S. natural gas supply and price to its market fundamental shocks different in recessions and expansions?
2. Are the responses of U.S. economic activity to oil and natural gas prices different over its business cycle?

Contributions and Main Findings

1. Examine the interrelations among oil prices, U.S. natural gas supply and prices, and U.S. economy
2. Study possible asymmetries in the reactions of the U.S. natural gas market and economic activity by utilizing a nonlinear framework (smooth-transition VAR)

1. Oil price shock is an important factor driving the production of natural gas, however the directions of impact are totally different depending on the economic condition
2. Relationship between oil and natural gas prices is more prominent in recessions in the short-run and in expansions in the long-run
3. U.S economy is much more sensitive to the energy price shocks in recession than in expansions

Benchmark Model

5. Benchmark model is a similar recursive VAR model consisting of four variables

$$\mathbf{z}_t = \boldsymbol{\alpha} + \sum_{i=1}^{p} \mathbf{A_i z_{t-i}} + \mathbf{e_t},$$

6. $\mathbf{z}_t = (rpo_t, \Delta prodg_t, \Delta ip_t, rpg_t)'$
    1. rpo_t: U.S. real oil price
    2. $\Delta prodg_t$: U.S. natural gas production growth
    3. Δip_t: U.S. real economic growth
    4. rpg_t: U.S. real natural gas price
7. Incorporate a smooth-transition into a benchmark model to capture asymmetric reactions

STVAR Model

1. Adopt a STVAR model

$$\mathbf{z}_t = (1 - F(s_{t-1}))\left(\boldsymbol{\alpha}^{(1)} + \sum_{i=1}^{p} \mathbf{A_i^{(1)}} \mathbf{z_{t-i}}\right) + F(s_{t-1})\left(\boldsymbol{\alpha}^{(2)} + \sum_{i=1}^{p} \mathbf{A_i^{(2)}} \mathbf{z_{t-i}}\right) + \mathbf{e_t},$$

2. One of the regime switching models
   1. Regime 1: $F = 0 \Longrightarrow \mathbf{z}_t = \boldsymbol{\alpha}^{(1)} + \sum_{i=1}^{p} \mathbf{A_i^{(1)}} \mathbf{z_{t-i}} + \mathbf{e_t}$
   2. Regime 2: $F = 1 \Longrightarrow \mathbf{z}_t = \boldsymbol{\alpha}^{(2)} + \sum_{i=1}^{p} \mathbf{A_i^{(2)}} \mathbf{z_{t-i}} + \mathbf{e_t}$
3. Model of $\mathbf{z}_t$ is a weighted average of each regime model

STVAR Model

4. Model regime transition with a logistic transition function $F(s_{t-1}; c, \gamma)$ between 0 and 1

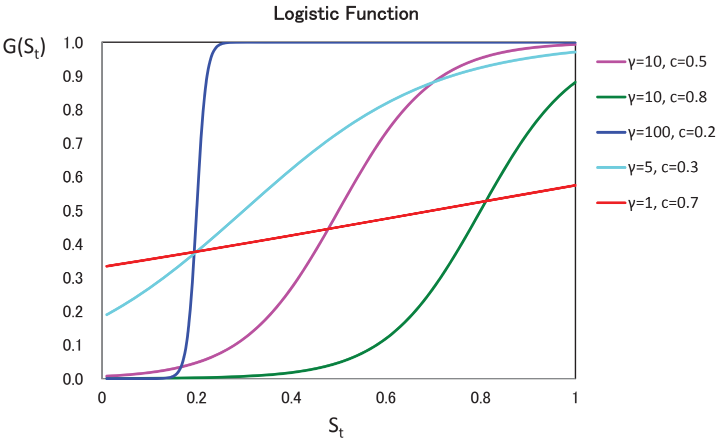
$$F(s_{t-1}; c, \gamma) = \frac{1}{1 + \exp(-\gamma(s_t - c))}, \quad \gamma > 0$$

   1. s_{t-1}: transition variable
   2. c: location parameter
   3. γ: smoothness parameter

5. s_t : average growth rate of U.S. real economy over the last p-months
   1. $\mathbf{A_i^{(1)}}$: dynamics of the system in the recession regime
   2. $\mathbf{A_i^{(2)}}$: dynamics of the system in the expansion regime

STVAR Model

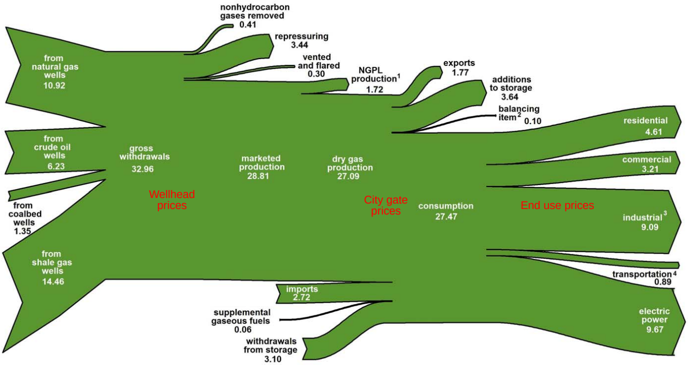
6. Can describe various patterns of transition depending on the values of c and γ



7. Can estimate the best pattern of transition from data

The US natural gas market

U.S. Natural Gas Flow, 2015
trillion cubic feet

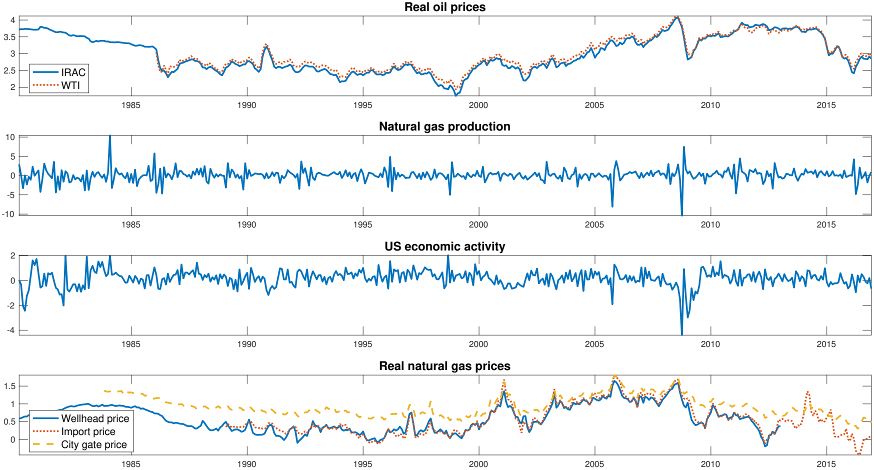


[1] Natural gas plant liquids production (NGPL), gaseous equivalent.
[2] Quantities lost and imbalances in data due to differences among data sources. Excludes transit shipments that cross the U.S.-Canada border (i.e., natural gas delivered to its destination via the other country).
[3] Lease and plant fuel, and other industrial.
[4] Natural gas consumed in the operation of pipelines (primarily in compressors) and as fuel in the delivery of natural gas to consumers, plus a small quantity used as vehicle fuel.
Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.
Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2016), Tables 4.1, 4.3, and 4.4; and EIA estimates based on previous year's data.

Empirical Analysis

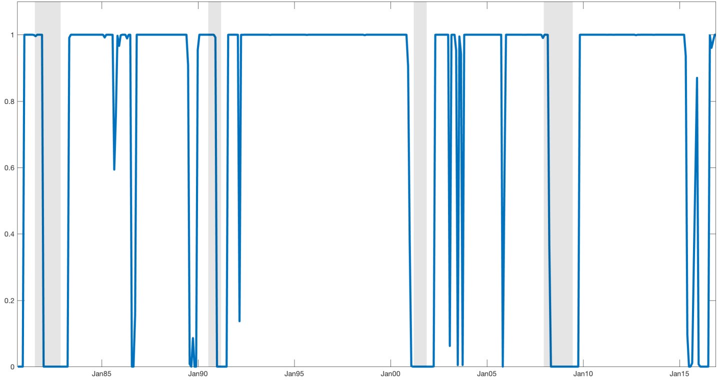
1. Monthly data from 1980M2-2016M11, sourced from EIA and Fed of St. Louis and real terms adjusted by US CPI
   - *rpo*: real prices of crude oil (US refiner's acquisition cost for imported crude oil - IRAC)
   - $\Delta prodg$: natural gas gross withdrawals (seasonally adjusted)
   - Δip: U.S. industrial production index (seasonally adjusted)
   - *rpg*: real wellhead prices (1980M2-2012M12) and import prices (2013M1-2016M11)
2. For robustness check
   - *rpo*: real price of crude oil (West Texas Intermediate - WTI)
   - *rpg*: real city gate prices
3. p is set to be 6
4. All estimations are conducted by maximum likelihood estimation assuming normality
5. Impulse response analysis is based on a recursive-design wild bootstrap with 2,000 replications, following Gonçalves and Kilian (2004) and Kilian (2009)

Historical evolution of the series

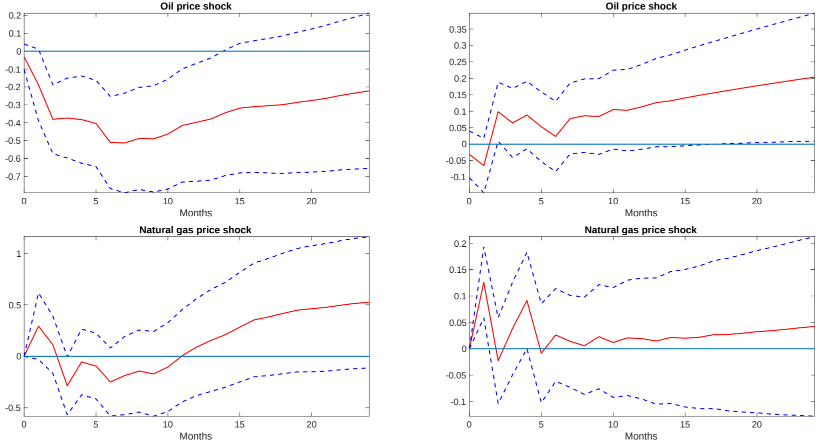


NBER dates and $F(s_{t-1})$

1. Estimates of c and γ are given by -0.036 and 106.8
2. Average growth rates is lower than -0.434% per year, the regime would become closer to the recession regime
3. Estimated regime dynamics reasonably corresponds to the business cycle



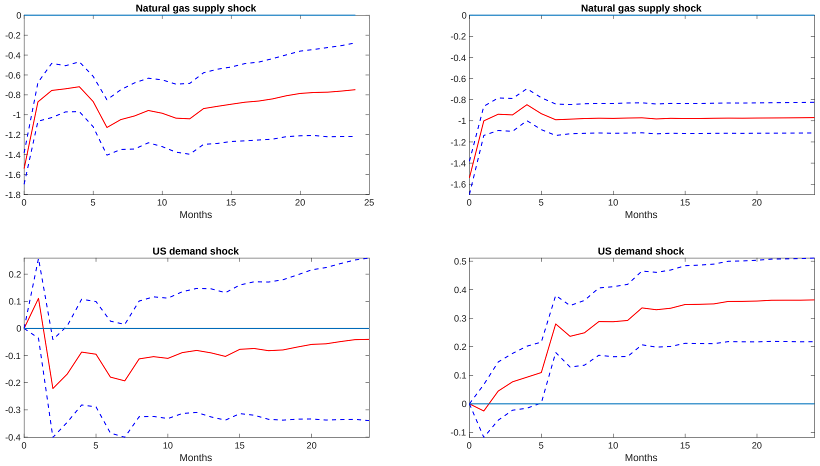
Natural gas production responses



Note: IRFs in left (right) are those for recessions (expansions)

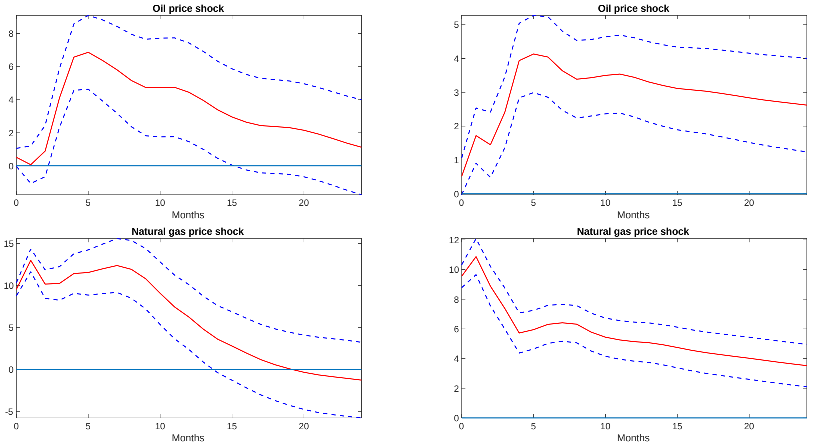
1. Oil price shock increases NG production only in expansions
2. NG production is not sensitive to the price of NG

Natural gas production responses



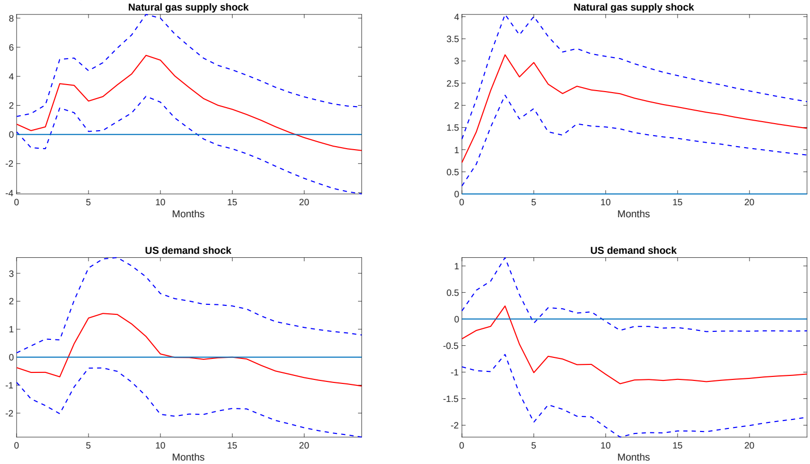
3. Strong positive responses of NG supply to the U.S. demand in the long run during an expansion

Natural gas price responses



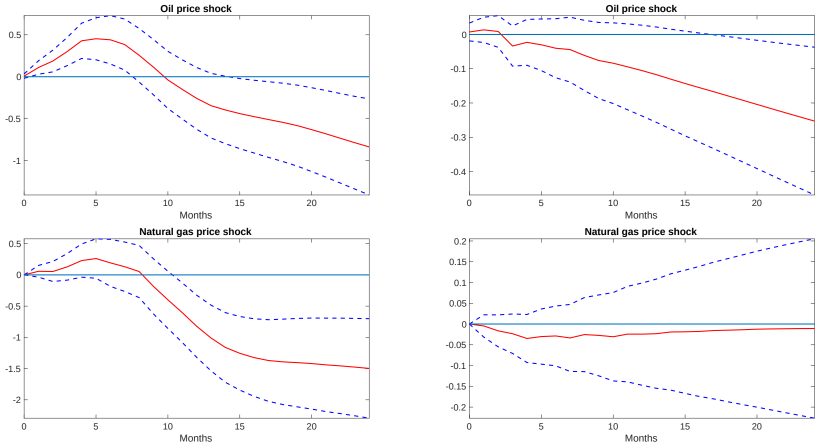
1. Impacts of oil and NG price shocks become insignificant in the long run in recessions
2. Oil and NG price shocks have significant positive effects on the NG price even in the long run in expansions

Natural gas price responses



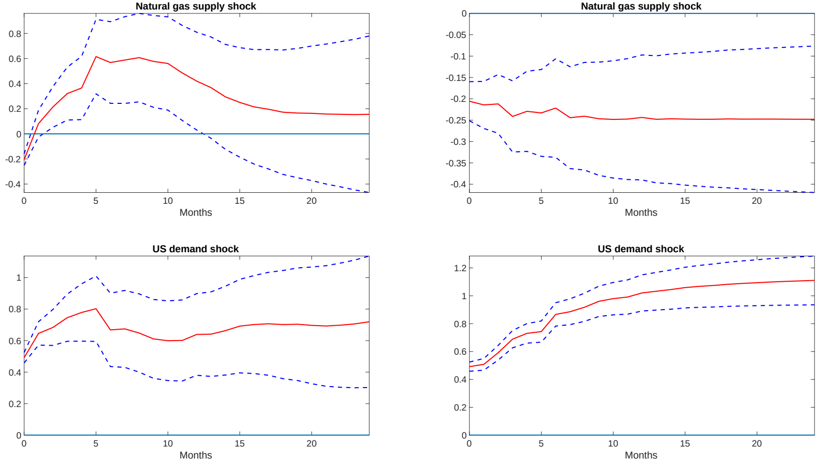
3. Negative supply shock induces higher natural gas prices in the long run only in expansions
4. U.S. demand shock negatively affects the natural gas price in the long run during expansions

US economic activity responses



1. Responses of U.S. economy to oil price shock become consistent with the previous studies
2. U.S. economic activity is much more sensitive to the shocks occurring in recession periods

US economic activity responses



1. Effect of NG supply shocks is not statistically significant in the long run in recessions
2. NG supply shock has persistent negative effect in expansions, partly due to NG price increases

Conclusion

1. Examine the interrelations among oil prices, U.S. natural gas supply and prices, and U.S. economy
2. Study possible asymmetries in the reactions of the U.S. natural gas market and economic activity by utilizing a nonlinear framework (smooth-transition VAR)

1. Oil price shock is an important factor driving the production of natural gas, however the directions of impact are totally different depending on the economic condition
2. Relationship between oil and natural gas prices is more prominent in recessions in the short-run and in expansions in the long-run
3. U.S economy is much more sensitive to shocks in recession than in expansions

References I

Atil, A., Lahiani, A., and Nguyen, D. K. (2014). Asymmetric and nonlinear pass-through of crude oil prices to gasoline and natural gas prices. *Energy Policy*, 65:567–573.

Bachmeier, L. J. and Griffin, J. M. (2006). Testing for market integration crude oil, coal, and natural gas. *The Energy Journal*, 27(2):55–71.

Baumeister, C. and Kilian, L. (2016a). Forty years of oil price fluctuations: Why the price of oil may still surprise us. *Journal of Economic Perspectives*, 30(1):139–60.

Baumeister, C. and Kilian, L. (2016b). Lower oil prices and the US economy: is this time different? *Brookings Papers on Economic Activity*, Fall 2016:287–336.

Baumeister, C. and Peersman, G. (2013). Time-varying effects of oil supply shocks on the US economy. *American Economic Journal: Macroeconomics*, 5(4):1–28.

Brigida, M. (2014). The switching relationship between natural gas and crude oil prices. *Energy Economics*, 43:48–55.

Brown, S. P. and Yücel, M. K. (2008). What drives natural gas prices? *The Energy Journal*, 29(2):45–60.

Gonçalves, S. and Kilian, L. (2004). Bootstrapping autoregressions with conditional heteroskedasticity of unknown form. *Journal of Econometrics*, 123(1):89–120.

Hamilton, J. D. (2003). What is an oil shock? *Journal of Econometrics*, 113(2):363–398.

References II

Hamilton, J. D. (2011). Nonlinearities and the macroeconomic effects of oil prices. *Macroeconomic Dynamics*, 15(S3):364–378.

Jadidzadeh, A. and Serletis, A. (2017). How does the US natural gas market react to demand and supply shocks in the crude oil market? *Energy Economics*, 63:66–74.

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review*, 99(3):1053–69.

Kilian, L. and Murphy, D. P. (2014). The role of inventories and speculative trading in the global market for crude oil. *Journal of Applied Econometrics*, 29(3):454–478.

Pindyck, R. S. (2004). Volatility in natural gas and oil markets. *The Journal of Energy and Development*, 30(1).

Ramberg, D. J. and Parsons, J. E. (2012). The weak tie between natural gas and oil prices. *The Energy Journal*, 33(2):13–35.

Serletis, A. and Rangel-Ruiz, R. (2004). Testing for common features in North American energy markets. *Energy Economics*, 26(3):401–414.

Zamani, N. (2016). How the crude oil market affects the natural gas market? Demand and supply shocks. *International Journal of Energy Economics and Policy*, 6(2):217–221.