The Impact of Shale Boom on North American Natural Gas Market

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1 Overview

Between 2010 and 2015, hydraulic fracturing and horizontal drilling revolutionized the U.S. and Canada petroleum and natural gas industries. According to U.S. Energy Information Administration (EIA), U.S. and Canada are the only major producers in the world of commercially viable natural gas from shale formations. By 2015, tight oil and shale gas accounted for nearly 50% of U.S. crude oil and natural gas productions. In 2015-2016, U.S. crude production averaged 278 thousand barrels per month, nearly a 70% increase over the 2000-2009 average of 164 thousand barrels per month. As well, the West Texas Intermediate (WTI) crude oil price averaged $65 per barrel during 2015-2016, compared to the 2008-2014 average of $87 dollars per barrel. Similarly, natural gas production in 2015-2016 averaged 2,720 billion cubic feet per month, a 34% increase from 2,030 billion cubic feet per month in 2000-2009. As well, in 2015-2016, natural gas prices were $4.08 per thousand cubic feet, only 60% of their 2000-2009 average of $6.79 per thousand cubic feet. These effects are shown in Figure 1.

In Canada, hydraulic fracturing has led to the increased productions of shale gas across the country, from British Columbia to New Brunswick. By 2015, Shale gas production reached 4.1 billion cubic feet per day (BCF/day), more than 20% of total Canadian natural gas production. The National Energy Board of Canada expects this development to continue to increase and to account for almost 70% of Canadian total natural gas production by 2025.

These changes have have reverberated through the industry. Natural gas consumption in the U.S. in 2015-2016 averaged 2.30 trillion cubic feet per month, which is 22% higher than

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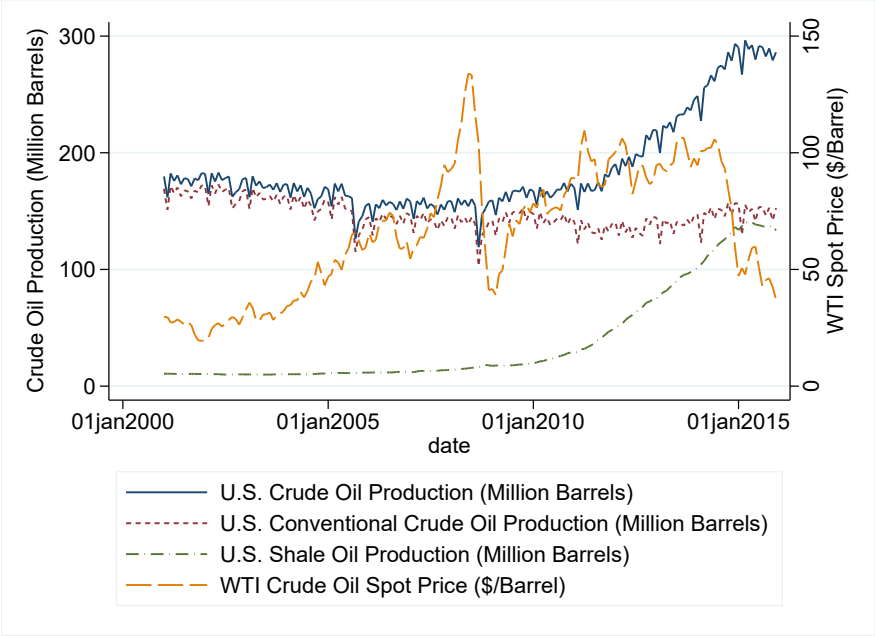
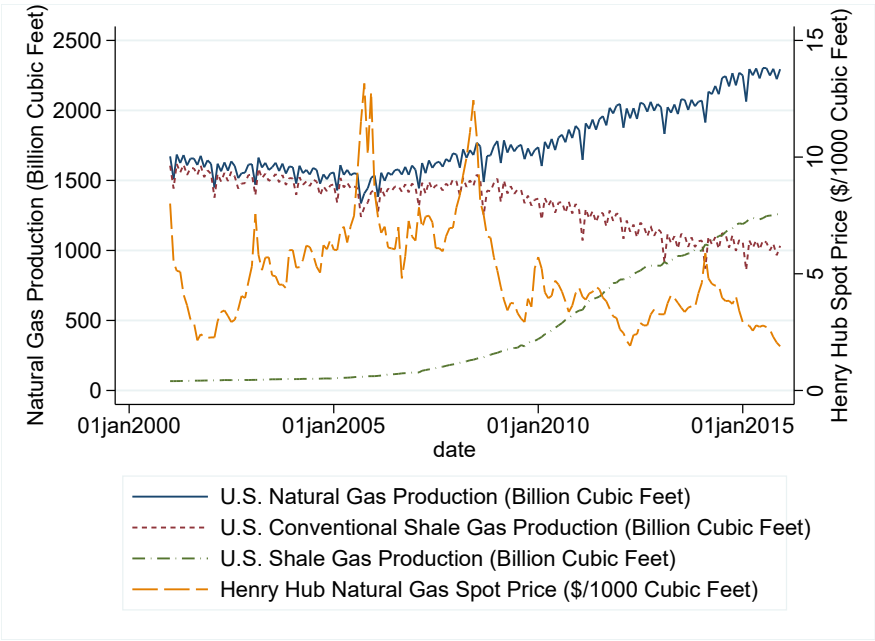
its 2000-2009 average of 1.87 trillion cubic feet per month. Similarly, underground storage of natural gas has risen by 11% to 7.33 trillion cubic feet from 6.33 trillion cubic feet.[1] Storage of natural gas is of particular importance to that market because of the large seasonal swings in demand and because natural gas pipeline transportation requires pressurization.

[1]Crude oil stores also rose dramatically to an average of 482 thousand barrels in 2015-16 from an average of 310 thousand barrels in 2000-09 (stores excluding strategic reserves). But unlike natural gas, stores in petroleum show now annual cycles. Also in contrast to natural gas, however, consumption of finished petroleum products averaged only 518 thousand barrels per month in 2015-16, down from the average of 543 thousand barrels per month in 2000-2009.

Figure 1: Effect of Hydraulic Fracturing on the U.S. Oil and Gas Industries



(a) Effect on the Oil Industry



(b) Effect on the Natural Gas Industry

Although hydraulic fracking has become the major growing source of energy production, research regarding its impact on the Noth American and world market still remains scare. Mason et al. (2015) describe the economic benefits of the shale gas boom, providing back-of-the-envelope estimates of the changes in consumer and producer surplus resulting from

hydraulic fracking. Hausman and Kellogg (2015) estimate U.S. supply and demand elasticities of natural gas and then derive the parallel shifting of supply and demand curves before and after the adoption of hydraulic fracking. They calculate the counterfactual equilibrium that would have prevailed in 2013 in the absence of hydraulic fracking. They conclude a net social benefit of $48 billion per year, by subtracting a loss of producer surplus from the consumer surplus. Kilian (2017), using a structural vector-autoregressive model, shows the global price of crude oil was lower by $10 per barrel than it would have been in the absence of hydraulic fracking.

2 Method

This paper comprehensively investigates the impacts of hydraulic fracturing on the North American natural gas market by combining U.S. state-level and Canadian provincial-level data. Recognizing the role of natural gas storage in mitigating unexpected shocks in the short run, we incorporate natural gas underground storage into a simple dynamic model by following the theory of inventory in commodity markets (Pindyck, 2001). We derive an equilibrium condition of natural gas storage across periods. On the one hand, the shadow value of natural gas storage refers to convenience yields (i.e., the marginal benefits by holding an extra unit of storage). This is due to the fact that holding storage avoids abrupt and costly adjustments of natural gas production in the short run (Pindyck, 1994; Mason, 2011). On the other hand, the full marginal cost by holding an extra unit of storage includes the unit cost of storage facility and an opportunity cost. This condition reveals that the equilibrium storage level is governed by the condition that the (marginal) convenience yield is equal to the full marginal cost of one extra unit of storage.

By incorporating the theory of storage, we then estimate a system of equations including the equations of rig counts, production, convenience yield, net import, and demand. The effect of hydraulic fracking on natural gas market is examined by allowing the slopes of rig counts, production and convenience yield equations to change with the expansion of hydraulic fracking. As a result, we are able to understand how the hydraulic fracking gradually changes the natural gas market for the past 10 years in a dynamic framework. We account for the endogenous natural gas price or storage on the right-hand side of each equation. We show our estimated results are robust by using different sets of instruments.

3 Results

Our analysis reveals how the expansion of hydraulic fracking has resulted in a more elastic supply in the North American natural gas market. First, the production from existing wells has become more elastic with the expansion of hydraulic fracking. This is because the current production is more responsive to the current real price with the expansion of hydraulic fracking. Second, since rig counts have become more responsive to changes in future prices and rig productivity has improved with the expansion of hydraulic fracking, the production from newly established rigs (wells) has also become more elastic. We find with only 2.3 BCF/day production from hydraulic fracking in 2001, an extra unit increase in future prices at 3 months earlier causes the average production currently to increase by 0.3 billion cubic feet. However, with the hydraulic fracking production reaching 42 BCF/day in 2015, one extra unit rise in future prices at 3 months earlier causes the average production currently to increase by 4.5 billion cubic feet.

Furthermore, we conclude that the convenience yield curve has become less steep and thus adjusting natural gas storage is more flexible with the expansion of hydraulic fracking. This is particularly important because holding storage is the major channel for producers and distributors to mitigate short-run risks (e.g., temperature shocks) in the North American natural gas market. We document that with the shale gas production at 2.3 BCF/day in 2001, one extra unit increase in convenience yields causes average storage to withdraw by 25 billion cubic feet. However, with emerging shale gas productions reaching 42 BCF/day in 2015, one extra unit increase in convenience yields causes average storage to withdraw by 273 billion cubic feet.

4 Conclusion

This paper provides a comprehensive analysis on the effect of hydraulic fracking on North American natural gas market. We estimate a system of equations regarding natural gas rig counts, production, convenience yield, demand and net import by using U.S. state-level and Canadian provincial level data. In order to account for the endogenous variables on the right-hand side of each equation, we apply different sets of instrument variables and show our estimated results are robust across different sets of instruments.

Our estimated results show significant changes in short-run market dynamics since the shale revolution. We find both the production from existing wells and the production from newly established wells have become more elastic with the expansion of hydraulic fracking.

As a result, the natural gas supply from the spot market has become more elastic with the expansion of hydraulic fracking.

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