Business Cycles and Natural Gas Prices

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Abstract

This paper investigates the basic stylized facts of natural gas price movements using data for the period that natural gas has been traded on an organized exchange and the methodology suggested by Kydland and Prescott (1990). Our results indicate that natural gas prices are procyclical and lag the cycle of industrial production. Moreover, natural gas prices are positively contemporaneously correlated with U.S. consumer prices and lead the cycle of consumer prices, raising the possibility that natural gas prices might be a useful guide for U.S. monetary policy, like crude oil prices are, possibly serving as an important indicator variable.

Key words: Stylized facts; Business cycles; Granger causality

JEL classification: E32

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1 Introduction

In recent years, the North American energy industry has undergone major structural changes that have significantly affected the environment in which producers, transmission companies, utilities and industrial customers operate and make decisions. For example, major policy changes are the U.S. Natural Gas Policy Act of 1978, Natural Gas Decontrol Act of 1989, and FERC Orders 486 and 636. In Canada, deregulation in the mid-1980s has also broken the explicit link between the delivered prices of natural gas and crude oil (that was in place prior to 1985), and has fundamentally changed the environment in which the Canadian oil and gas industry operates. Moreover, the Free Trade Agreement (FTA) signed in 1988 by the United States and Canada, and its successor, the North American Free Trade Agreement (NAFTA) signed in 1993 by the United States, Canada, and Mexico, have underpinned the process of deregulation and attempted to increase the efficiency of the North American energy industry.

In this paper we systematically investigate the cyclical behavior of natural gas price movements for the period that natural gas has been traded on an organized exchange. The cyclical behavior of energy prices, in general, is important and has been the subject of a large number of studies, exemplified by Hamilton (1983). These studies have, almost without exception, concentrated on the apparently adverse business-cycle effects of oil price shocks. For example, Hamilton (1983) working on pre-1972 data and based on vector autoregression (VAR) analysis, concluded that energy prices are countercyclical and lead the cycle. More recently, however, Serletis and Kemp (1998) show, using data over the period for which energy has been traded on organized exchanges and the methodology suggested by Kydland and Prescott (1990), that energy prices are in general procyclical.

The paper is organized as follows. Section 2 uses the Hodrick and Prescott (1980) and Baxter and King (1999) filtering procedures for decomposing time series into long-run and business cycle components and presents empirical correlations of natural gas prices with U.S. industrial production and consumer prices, as well as with West Texas Intermediate (WTI) crude oil, heating oil, and propane prices. Section 3 tests for Granger causality, explicitly taking into account the univariate and bivariate properties of the variables. The final section summarizes the paper.
2 The Stylized Facts

In this section we investigate the basic stylized facts of natural gas price movements, using stationary cyclical deviations based on the Hodrick and Prescott (1980) and the Baxter and King (1999) filters; see Hodrick and Prescott (1980) and Baxter and King (1999) for more details regarding these filters. In doing so, we use monthly data from January 1990 to March 2002 (a total of 147 monthly observations) and define natural gas cycle regularities as the dynamic comovements of the cyclical component of natural gas prices and the cycle. In particular, the business cycle regularities that we consider are autocorrelations and dynamic cross-correlations between the cyclical component of natural gas prices, on the one hand, and the cyclical component of U.S. industrial production on the other.

We measure the degree of comovement of natural gas prices with the cycle by the magnitude of the correlation coefficient \( \rho(j) \), \( j \in \{0, \pm 1, \pm 2, \ldots \} \). The contemporaneous correlation coefficient \( -\rho(0) \) gives information on the degree of contemporaneous comovement. In particular, if \( \rho(0) \) is positive, zero, or negative, we say that the series is procyclical, acyclical, or countercyclical, respectively. In fact, following Fiorito and Kollintzas (1994), for \( 0.23 \leq |\rho(0)| < 1, 0.10 \leq |\rho(0)| < 0.23, \) and \( 0 \leq |\rho(0)| < 0.10, \) we say that the series is strongly contemporaneously correlated, weakly contemporaneously correlated, and contemporaneously uncorrelated with the cycle, respectively.\(^1\) The cross correlation coefficient, \( \rho(j) \), \( j \in \{\pm 1, \pm 2, \ldots \} \), gives information on the phase shift of natural gas relative to the cycle. If \( |\rho(j)| \) is maximum for a positive, zero, or negative \( j \), we say that the cycle of natural gas prices is leading the cycle by \( j \) periods, is synchronous, or is lagging the cycle by \( j \) periods, respectively.

Table 1 reports the contemporaneous correlations as well as the cross correlations based on the Hodrick-Prescott (Panel A) and Baxter-King (Panel B) filters, at lags and leads of 1, 2, 3, 6, 9, and 12 months, between the cyclical component of spot Henry Hub natural gas prices and the cyclical component of each of U.S. industrial production, U.S. consumer prices, West Texas Intermediate crude oil prices, heating oil prices, and propane prices. The industrial production and consumer price indexes were obtained from

\(^1\)The cutoff point of 0.1 is close to the value of 0.097 that is required to reject the null hypothesis \( H_0 : \rho(0) = 0 \) at the 5\% level. Also, the cutoff point of 0.23 is close to the value of 0.229 that is required to reject the null \( H_0 : |\rho(0)| \leq 0.5 \) at the 5\% level.
the Federal Reserve Economic Database (FRED), maintained by the Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred/index.html). The spot crude oil and natural gas prices were obtained from the Oil & Gas Journal’s database (http://orc.pennnet.com/home.cfm). Finally, the spot heating oil and propane prices were obtained from the U.S. Energy Information Administration (http://www.eia.doe.gov).

Clearly, irrespective of the filter used, natural gas prices are procyclical and lag the cycle (of industrial production). This is consistent with the evidence reported by Serletis and Kemp (1998) using spot-month NYMEX natural gas futures prices (as a proxy for the spot price) over a much shorter sample period (with only 37 monthly observations). Moreover, (regardless of which filter is used) natural gas prices are positively contemporaneously correlated with U.S. consumer prices and the cycle of natural gas leads the cycle of consumer prices, suggesting that changes in natural gas prices might be good predictors of future aggregate price changes. Finally, the contemporaneous correlation of natural gas prices is strikingly strong with crude oil, heating oil, and to a larger extent with propane, suggesting that these markets are perhaps driven by one common trend — see Serletis (1994) for work along these lines.

In the next section we investigate whether the apparent phase-shift between natural gas prices and each of the other variables justifies a causal relationship between these variables. In doing so, we interpret causality in terms of predictability and not as suggesting the existence of underlying structural relationships between the variables.

### 3 Granger Causality Tests

The first step in testing for causality is to test for the presence of a stochastic trend in the autoregressive representation of each (logged) individual time series. In the first three columns of Table 2 we report $p$-values [based on the response surface estimates given by MacKinnon (1994)] for the weighted symmetric (WS) unit root test [see Pantula, Gonzalez-Farias, and Fuller (1994)], the augmented Dickey-Fuller (ADF) test [see Dickey and Fuller (1981) for more details], and the nonparametric $Z(t_{\alpha})$ test of Phillips and Perron (1987). As discussed in Pantula et al. (1994), the WS test dominates the ADF test in terms of power. Also the $Z(t_{\alpha})$ test is robust to a wide variety of serial correlation and time-dependent heteroskedasticity. For the WS and ADF
tests, the optimal lag length is taken to be the order selected by the Akaike Information Criterion (AIC) plus 2 — see Pantula et al. (1994) for details regarding the advantages of this rule for choosing the number of augmenting lags. The $Z(t_{\hat{\alpha}})$ test is done with the same Dickey-Fuller regression variables, using no augmenting lags. According to these $p$-values, the null hypothesis of a unit root in log levels cannot be rejected except for heating oil, suggesting that these series are integrated of order 1 [or I(1) in the terminology of Engle and Granger (1987)].

Next we explore for shared stochastic trends between natural gas prices and each of the other I(1) variables using methods recommended by Engle and Granger (1987). That is, we test for cointegration (i.e., long-run equilibrium relationships). If the variables are I(1) and cointegrate, then there is a long-run equilibrium relationship between them. Moreover, the dynamics of the cointegrated variables can be described by an error correction model, in which the short-run dynamics are influenced by the deviation from the long-run equilibrium. If, however, the variables are I(1) but do not cointegrate, ordinary least squares yields misleading results. In that case, the only valid relationship that can exist between the variables is in terms of their first differences.

We test the null hypothesis of no cointegration (against the alternative of cointegration) between natural gas prices and each of the other I(1) variables using the Engle and Granger (1987) two-step procedure. The tests are first done with natural gas as the dependent variable in the cointegrating regression and then repeated with each of the other I(1) variables as the dependent variable. The results, under the ‘Cointegration’ columns of Table 2, suggest that the null hypothesis of no cointegration between natural gas prices and each of the other I(1) variables cannot be rejected (at the 5% level) in all cases.

Since we are not able to find evidence of cointegration, to avoid the spurious regression problem we test for Granger causality in the context of the following system.

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2 This is consistent with the evidence recently reported by Serletis and Andreadis (2004). In particular, they use daily observations on WTI crude oil prices at Chicago and Henry Hub natural gas prices at Louisiana (over the deregulated period of the 1990s) and various tests from statistics and dynamical systems theory to support a random fractal structure for North American energy markets.
\[ \Delta y_t = \alpha_1 + \sum_{j=1}^{r} \alpha_{11}(j) \Delta y_{t-j} + \sum_{j=1}^{s} \alpha_{12}(j) \Delta x_{t-j} + \varepsilon_{yt}, \]

(1)

\[ \Delta x_t = \alpha_2 + \sum_{j=1}^{r} \alpha_{21}(j) \Delta y_{t-j} + \sum_{j=1}^{s} \alpha_{22}(j) \Delta x_{t-j} + \varepsilon_{xt}, \]

(2)

where \( \alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22} \) are all parameters and \( \varepsilon_{yt} \) and \( \varepsilon_{xt} \) are white noise disturbances. As in the previous section, we use \( x_t \) to denote logged natural gas prices and \( y_t \) to denote the logarithm of each of the other variables; since heating oil is a stationary series, its logged level is used in (1) and (2) instead of its logarithmic first difference.

In the context of (1) and (2) the causal relationship between \( y_t \) and \( x_t \) can be determined by first fitting equation (1) by ordinary least squares and obtaining the unrestricted sum of squared residuals, \( SSR_u \). Then by running another regression equation under the null hypothesis that all the coefficients of the lagged values of \( \Delta x_t \) are zero, the restricted sum of squared residuals, \( SSR_r \), is obtained. The statistic

\[ \frac{(SSR_r - SSR_u)}{SSR_u/(T-1-r-s)}, \]

has an asymptotic \( F \)-distribution with numerator degrees of freedom \( s \) and denominator degrees of freedom \( (T-1-r-s) \). \( T \) is the number of observations, \( r \) represents the number of lags of \( \Delta y_t \) in equation (1), \( s \) represents the number of lags for \( \Delta x_t \), and 1 is subtracted out to account for the constant term in equation (1).

If the null hypothesis cannot be rejected, then the conclusion is that the data do not show causality. If the null hypothesis is rejected, then the conclusion is that the data do show causality. The roles of \( y_t \) and \( x_t \) are reversed in another \( F \)-test [as in equation (2)] to see whether there is a feedback relationship among these series.

We used the AIC with a maximum value of 12 for each of \( r \) and \( s \) in (1) and (2) and by running 144 regressions for each bivariate relationship we chose the one that produced the smallest value for the AIC. We present these optimal lag length specifications in the last two columns of Table 2 together with \( p \)-values for Granger causality \( F \)-tests based on the optimal specifications. Clearly, there is evidence of a feedback relationship between natural gas prices and consumer prices (at about the 1% level). There is no
evidence of industrial production causing natural gas prices, although in the previous section we established that natural gas prices are procyclical and lagging the cycle.

Finally, there is no evidence of a causal relationship between crude oil prices and natural gas prices. This is perhaps due to the fact that the Henry Hub natural gas market is much more segmented than the WTI crude oil market. For example, when crude oil prices change, they tend to change world-wide whereas the price of natural gas can easily change in North America without any changes in natural gas prices in other continents. This follows because transportation of natural gas by pipeline is far cheaper than transportation by ship (liquefied natural gas).

4 Conclusion

We have investigated the cyclical behavior of natural gas prices, using monthly data for the period that natural gas has been traded on organized exchanges and the methodology suggested by Kydland and Prescott (1990). Based on stationary Hodrick and Prescott (1980) and Baxter and King (1999) cyclical deviations, our results indicate that natural gas prices are procyclical and lag the cycle of industrial production. Moreover, natural gas prices are positively contemporaneously correlated with U.S. consumer prices and lead the cycle of consumer prices, raising the possibility that natural gas prices might be a useful guide for U.S. monetary policy, like crude oil prices are, possibly serving as an important indicator variable.

However, using lead-lag relationships to justify causality is tenuous. For this reason we also investigated the causality relationship between natural gas prices and U.S. industrial production and consumer prices, as well as between natural gas prices and each of crude oil, heating oil, and propane prices. This examination utilized state-of-the-art econometric methodology, using the single-equation approach. Our results indicate that industrial production does not Granger cause natural gas prices (although natural gas prices are procyclical and lag the cycle) and that there is a feedback relationship between natural gas prices and consumer prices.

Our results regarding the absence of a causal relationship between natural gas prices and crude oil prices are consistent with the evidence recently reported by Serletis and Rangel-Ruiz (2004) who investigate the strength of shared trends and shared cycles between WTI crude oil prices and Henry
Hub natural gas prices using daily data from January, 1990 to April, 2001. Based on recently suggested testing procedures they reject the null hypotheses of common and codependent cycles, suggesting that there has been ‘decoupling’ of the prices of these two energy sources as a result of oil and gas deregulation in the United States.
References


TABLE 1
Cyclical Correlations of Natural Gas Prices with Industrial Production, Consumer Prices, crude oil, heating oil, and propane

\[ \rho(x_t, y_{t+j}), \ j = -12, -9, -6, -3, -2, -1, 0, 1, 2, 3, 6, 9, 12 \]

<table>
<thead>
<tr>
<th></th>
<th>( j = -12 )</th>
<th>( j = -9 )</th>
<th>( j = -6 )</th>
<th>( j = -3 )</th>
<th>( j = -2 )</th>
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<th>( j = 3 )</th>
<th>( j = 6 )</th>
<th>( j = 9 )</th>
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<tr>
<td><strong>Panel A. Hodrick and Prescott Filter</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Industrial production</td>
<td>-.033</td>
<td>.150</td>
<td>.354</td>
<td>.419</td>
<td>.403</td>
<td>.376</td>
<td>.338</td>
<td>.271</td>
<td>.212</td>
<td>.131</td>
<td>-.128</td>
<td>-.324</td>
<td>-.329</td>
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<td>Consumer prices</td>
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<td>.043</td>
<td>.138</td>
<td>.282</td>
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<td>.473</td>
<td>.578</td>
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<td>.670</td>
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<td>.429</td>
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<td>.365</td>
<td>.457</td>
<td>.488</td>
<td>.508</td>
<td>.514</td>
<td>.487</td>
<td>.428</td>
<td>.350</td>
<td>.106</td>
<td>-.110</td>
<td>-.283</td>
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<tr>
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<td>.585</td>
<td>.610</td>
<td>.612</td>
<td>.553</td>
<td>.476</td>
<td>.386</td>
<td>.115</td>
<td>-.110</td>
<td>-.308</td>
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<td>.562</td>
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<td>.485</td>
<td>.390</td>
<td>.171</td>
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<td>.478</td>
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<td>.492</td>
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<td>.558</td>
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<td>.384</td>
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<td>.442</td>
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<td>.615</td>
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NOTE: Results are reported using monthly data for the period January 1990 to March 2002. \( x_t \) = Natural gas, \( y_t \) = (Industrial production, Consumer prices, Crude oil, Heating oil, Propane).
<table>
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<td>y</td>
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<td>.161 .715</td>
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NOTE: Results are reported using monthly data for the period January 1990 to March 2002. 

x_t = Natural gas, y_t = (Industrial production, Consumer prices, Crude oil, Heating oil, Propane).