Asymmetric long–run effects in the oil industry*

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ABSTRACT

This paper analyzes long term dependence between the market value of oil firms and oil prices. Applying nonlinear cointegration, the results show that in the long-run oil price hikes and falls show different adjustments to the equilibrium. Using a momentum threshold autoregressive model (MTAR), we find that for oil producing firms, the adjustment is faster for oil price falls than for oil price hikes, but we do not find a difference on the speed of adjustment for oil integrated firms. Moreover, testing for asymmetric cointegration, we also find that oil price falls impact substantially the value of oil producers and integrated firms, but the same is not found for oil price hikes. Overall, the evidence suggests that firm value stays above equilibrium relationship when there are oil price hikes.

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I. Introduction

It is well documented in the literature that stock returns of oil firms are associated with changes in oil prices and stock market returns (see e.g. Boyer and Filion, 2007; El-Sharif et al., 2005; Nandha and Faff, 2008; Ramos and Veiga, 2011; Sadorsky, 1999, 2001). Studies also show that there is an asymmetric relationship between stock returns and oil price changes, i.e., the increase in industry returns with oil price hikes is proportionally greater than the decrease resulting from falls in oil prices, disclosing a pass-through effect. Ramos and Veiga (2011) discuss that firms can pass price increases through customers, either because demand is not sufficiently depressed by price spikes or firms in this industry have considerable market power. Both effects together can explain why positive changes in oil prices influence oil and gas stock returns more than negative changes.

Despite investors' and corporate managers' concern about long term risks, the analysis continues to focus on short term variations that are subject to considerable noise. Therefore, a long term view is potentially more helpful in understanding the underlying drivers of the market value of the oil industry.

Our work analyzes whether there is a long term relationship between oil prices and firm value and, if so, the nature of the relationship. We use data from December 1987 to August 2011 on U.S. oil industry firms, covering both oil producer and exploration firms, and oil integrated firms. These firms face common exposure to fluctuating prices of a commodity traded globally.

Cointegration is commonly used to analyze long term dependence between variables, and this methodology has been refined to accommodate nonlinear time series behavior, i.e., to account for the possibility that the relationship between the variables might not be the same whenever they increase or decrease. Given the evidence of asymmetric responses, we propose to use two nonlinear cointegration methods. First, we estimate the momentum threshold autoregressive (MTAR) model developed by Enders and Siklos (2001) designed to detect asymmetric short run adjustments to the long run equilibrium between variables. This specification is especially relevant when the adjustment is such that the series exhibits more momentum in one direction than the other. Second, we also use the concept of asymmetric cointegration developed by Schorderet (2003) that allows the existence of cointegration among nonstationary components of data series rather than the series themselves.

The results are as follows: We document a nonlinear long term relation between the market value of oil firms and oil prices, supporting the conjecture of non-symmetric adjustments to the long term equilibrium. Our findings complement the literature that reports evidence of asymmetric reactions in the short run (Nandha and Faff, 2008; Ramos and Veiga, 2011).

Our analysis differentiates between the adjustment for oil producers and for oil integrated firms. Oil is simultaneously the main output of the exploration and production industry and an input for integrated firms. Thus, depending on the price elasticity of oil, oil price hikes may generate higher revenues for the upstream segment and an increase of input costs followed by a reduction of supply in the petroleum refinery (Lee and Ni, 2002). We therefore investigate whether the impact of oil price changes is equal along the oil business value chain.

Using a MTAR model, the results show that the adjustment for oil producers is faster in the case of oil price falls, suggesting that firm value stays above the equilibrium relationship whenever there are price hikes. We do not find this relation for integrated firms.

Using Schorderet (2003)'s asymmetric cointegration concept, we also find that oil producers and integrated firms are cointegrated with oil when there is a fall in oil prices.

To our knowledge, this paper is the first to analyze the nonlinear adjustment of oil firm value to oil prices from a long term perspective. Our results are helpful in understanding the impact of oil price in the oil and gas industry market value. Besides short run asymmetric responses, oil firm value changes in the long run asymmetrically with oil price changes. Moreover, the results show a distinction between the relation of oil prices and oil producers, and oil prices and integrated firms. The former exhibits more dependence on oil price changes. Overall, our results have implications for investment and risk management decisions. In particular, they indicate that investors should hedge against losses resulting from oil price falls mainly for investments in oil producing firms, while corporate managers should engage in hedging strategies to protect firm value from oil price falls.

The paper is organized as follows. Section II reviews the literature. Section III describes the data and the summary statistics. Section IV reports the results obtained with the different cointegration concepts. Section V provides a discussion and concludes.

II. Review of Literature

The interest of investors in oil companies has grown with the upsurge in oil prices. A number of works have looked for drivers of returns in the oil and natural gas industry, such as the market portfolio, interest and currency rates, as well as oil prices. The evidence confirms that oil and gas companies' returns follow stock market and oil returns. Faff and Brailsford (1999) for Australian oil and gas industry equity returns, Sadorsky (2001) and Boyer and Filion (2007) for Canada, El-Sharif et al. (2005) for U.K., Al-Mudaf and Goodwin (1993) for the U.S., Park and Ratti (2008) and Oberndorfer (2009) for Europe and Ramos and Veiga (2011) for a sample of 34 countries. The above work has examined this question using both multifactor models (Basher and Sadorsky, 2006; Nandha and Faff, 2008; Sadorsky, 2008; Ramos and Veiga, 2011), and vector autoregressive models (Cong et al., 2008; Park and Ratti, 2008; Sadorsky, 1999).

An important finding is that oil and gas industry returns respond asymmetrically to changes in oil prices, i.e., oil price rises have a greater impact on stock returns than oil price drops (the so-called asymmetric effects). This evidence is pervasive at international level. Both Nandha and Faff (2008) using global industry indices and Ramos and Veiga (2011) using a sample of oil industries of 34 countries, find evidence of a pass-through effect in the oil industry. The increase in industry returns with oil price hikes is proportionally greater than the decrease resulting from falls in oil prices.

Few papers have distinguished the impact of oil price changes inside the oil industry. Aleisa et al. (2004) and Scholtens and Wang (2008) do not find differences between oil and gas producers (upstream) and the equipment, services and distribution companies (downstream). Boyer and

Filion (2007) using a sample of Canadian firms find that integrated firms only show sensitivity to market returns and to oil and natural gas; whereas producers show also sensitivity to exchange rate and interest rates. Recently, Ramos et al. (2012) have analyzed the presence of asymmetry in the upstream and downstream segment of the U.S. oil industry. They find that both stock returns of both upstream and downstream firms follow stock market and oil price returns, but the evidence for asymmetric effects is more pervasive across measures and time on the upstream segment.

However, few works have investigated the long term relation between oil and oil firm value. Aleisa et al. (2004) is an exception; using Johansen cointegration tests they find that price shocks in oil futures explain price movements in Standard & Poor oil indexes.

More recently, nonlinear cointegration methods have been applied to analyze long term dependence of stock markets on oil (see e.g. Maghyereh and Al-Khandari, 2007; Zhu et al., 2011) and of Gross Domestic Product on oil prices (see Lardic and Mignon, 2008).

III. Data

The sample includes monthly stock prices of oil exploration and production, and of integrated firms (usually petroleum refiners) of the U.S. oil industry (*expl&prod* and *integ*, respectively), the U.S. market (*market*) and the oil prices (*oil*) from December 1987 to August 2011. Data are drawn from Datastream. More details on the sample are given below.

The oil industry Following Boyer and Filion (2007), we split our sample of firms into producers and integrated firms. We use Datastream Industry Classification and extract U.S. subsector indexes of oil exploration and production and integrated firms.

Exploration and production refers to the initial part of oil value chain, where firms look for new oil resources and bring them to the surface. Oil and natural gas are the main outputs of this industry.

Integrated oil and gas companies are firms that participate in every aspect of the oil or gas business, which includes the discovering, obtaining, production, refining, and distribution of oil and gas. Oil is transformed into an array of products, including gasoline, distillate fuels, and jet fuel that are used in other industry businesses. Research work documents that there is a relation between the price of crude oil and refined products (see Asche et al., 2003; Girma and Paulson, 1999; Serletis, 1994). Therefore, it is likely that integrated firms show some sensitivity to changes in oil prices.

Market Previous studies are unanimous about the relation between the market returns and oil firm stock returns. Thus our analysis controls for the long term dependence on the U.S. stock market. To proxy the U.S. market, we use the stock market price index computed by Datastream (*market*), a value weighted price index.

Oil Oil prices are from the settlement price of the NYMEX oil futures contract, the most widely traded futures contract on oil. The underlying asset is the West Texas Intermediate oil; this is a light crude oil widely used as a current benchmark for U.S. crude production. Prices are in U.S. dollars per barrel (U$/BBL)(*oil*).

Summary statistics Table I describes the summary statistics of the variables *expl&prod*, *integ*, *market* and *oil*. The monthly mean returns range from 0.6% for the U.S. market returns to 0.8% for *integ* returns. Oil returns have the highest standard deviation (0.095%). Moreover, all series depict high values of skewness and kurtosis leading to the rejection of the null hypothesis of normality.

Table II shows the correlation coefficients among the four series. The two segments of the U.S. oil industry are highly correlated (0.934). We also find a high correlation between each industry and the oil prices, although oil prices are slightly more correlated with segment producers than with integrated firms. The correlations are 0.958 and 0.860, respectively. Oil and stock market prices are the least correlated (0.600). The correlation between stock market prices and *integ* (*expl&prod*) prices is 0.897 (0.705).

Figures 1 and 2 plot the four series of prices in logarithms. We can observe a clear comovement among them, especially from October 2003 until the end of the sample, and a close comovement of the *expl&prod* (*integ*) and oil prices in the sample. A closer look at the figures allows us to detect a lagged comovement between *expl&prod* (*integ*) and oil prices. In particular, a sharp decrease of oil price in the middle of sample is followed in the next months by decreases in the *expl&prod* and *integ* prices. Moreover, market prices seem to diverge from the other price series in the middle of the sample. Overall, there seems to be a time-varying long-run relationship among the price series and an asymmetric long-run relationship between *expl&prod* (*integ*) and oil prices that cannot be detected using the usual concept of cointegration.

Unit root tests Following Shen et al. (2007) and Lardic and Mignon (2008), we proceed by detecting if there are unit roots in each price series by applying the Augmented Dickey-Fuller (ADF) test directly to the logarithms of the series of prices. Table III reports the results of the unit root tests. We do not reject the the null hypothesis of a unit root for any of the series in levels. We proceed by applying the ADF test to the return series and conclude that they are stationary. Therefore, the overall unit root tests indicate that all price series are integrated of order one ($I(1)$).

Engle-Granger cointegration test The series are cointegrated if they are $I(1)$, but there is a linear combination among them that is stationary ($I(0)$). With the purpose of testing for cointegration, we estimate the following regressions by OLS:

$$expl\&prod_t = a_0 + a_1 oil_t + a_2 market_t + e_{1t} \tag{1}$$

and

$$integ_t = b_0 + b_1 oil_t + b_2 market_t + e_{2t}, \tag{2}$$

and we apply the ADF test to the residuals of the previous regressions ($\hat{e}_{1t}$ and $\hat{e}_{2t}$).[1] The results of the ADF on the series of residuals are listed in Table IV. In both cases, we do not reject the null of unit root implying that the previous series of prices are not linearly cointegrated. The results are not surprising since the usual concept of cointegration is restrictive and as we have mentioned previously, there seems to be a time-varying long-run relationship among these variables. In the next section, we present broader concepts of cointegration that may help us understand the long-run relationship among these variables.

IV. Cointegration

In this section we describe two types of cointegration. The first is the nonlinear cointegration also denoted momentum threshold cointegration. The second is the asymmetric cointegration that allows positive and negative partial sums to have a different effect on the long-run relationship among variables. A major strength of these methods is that they account for the possibility of asymmetric adjustments in the variables.

A. Nonlinear cointegration

Suppose that three variables y_t, x_t and z_t are $I(1)$. In order to confirm whether these variables have a nonlinear cointegration relationship, we apply the two-step methodology proposed by Enders and Siklos (2001). The procedure is as follows. First, we estimate the long-run equilibrium relationship among y_t, x_t and z_t as:

$$y_t = c_0 + c_1 x_t + c_2 z_t + \varepsilon_t, \tag{3}$$

where c_0, c_1 and c_2 are the parameters and ε_t is a disturbance term. If variables y_t, x_t and z_t are cointegrated, then the OLS estimators converge faster than those of the stationary variables for the true values of the parameters. Second, we determine if ε_t is stationary. Enders and Granger

[1]We keep the lags that are statistical significant in the auxiliary regression of the ADF test.

(1998) and Enders and Siklos (2001) consider the following momentum-threshold autoregressive cointegration model (M-TAR):

$$\Delta\varepsilon_t = M_t\rho_1\varepsilon_{t-1} + (1 - M_t)\rho_2\varepsilon_{t-1} + \sum_{i=1}^{k}\delta_i\Delta\varepsilon_{t-i} + \epsilon_t, \quad (4)$$

where ρ_1, ρ_2 and δ_i are coefficients, ϵ_t is a white-noise disturbance, k is the number of lags and M_t is an indicator function such that:

$$M_t = \begin{cases} 1 & \text{if } \ \Delta\varepsilon_{t-1} \geq 0 \\ 0 & \text{if } \ \Delta\varepsilon_{t-1} < 0. \end{cases} \quad (5)$$

The variables y_t, x_t and z_t are nonlinear cointegrated, if the null hypothesis of no cointegration ($H_0 : \rho_1 = \rho_2 = 0$) and the null hypothesis of symmetric adjustment ($H_0 : \rho_1 = \rho_2$) are both rejected. The F-statistics for the null hypothesis of no cointegration using the M-TAR model is denoted Φ^* and has a nonstandard distribution (see Enders and Siklos, 2001, for details and critical values). On the other hand, once we have rejected the first null hypothesis, the second test of symmetric adjustment follows a standard F-distribution. The rejection of this second null hypothesis means that if y_{t-1} is above its long-run equilibrium, the adjustment in the next period is ρ_1, and ρ_2 if y_{t-1} is below the long-run equilibrium relationship.

The MTAR model permits the adjustment process to depend on the previous period's error change and it is useful if the adjustment process exhibits more momentum in one direction than the other. M is known as the heaviside indicator. Within the MTAR model, one can examine the differential effects of the positive versus the negative phases of changes in oil prices on the behavior of oil firm value.

The nonlinear error-correction models for y_t, x_t and z_t are:

$$\Delta y_t = \alpha_0 + \theta_{11}M_t\hat{\varepsilon}_{t-1} + \theta_{12}(1 - M_t)\hat{\varepsilon}_{t-1} + \sum_{i=1}^{k}\alpha_{1i}\Delta y_{t-i} + \sum_{i=1}^{k}\alpha_{2i}\Delta x_{t-i} + \sum_{i=1}^{k}\alpha_{3i}\Delta z_{t-i} + \epsilon_{1t}, \quad (6)$$

$$\Delta x_t = \beta_0 + \theta_{21} M_t \hat{\varepsilon}_{t-1} + \theta_{22}(1 - M_t)\hat{\varepsilon}_{t-1} + \sum_{i=1}^{k} \beta_{1i} \Delta y_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta x_{t-i} + \sum_{i=1}^{k} \beta_{3i} \Delta z_{t-i} + \epsilon_{2t} \quad (7)$$

and

$$\Delta z_t = \psi_0 + \theta_{31} M_t \hat{\varepsilon}_{t-1} + \theta_{32}(1 - M_t)\hat{\varepsilon}_{t-1} + \sum_{i=1}^{k} \psi_{1i} \Delta y_{t-i} + \sum_{i=1}^{k} \psi_{2i} \Delta x_{t-i} + \sum_{i=1}^{k} \psi_{3i} \Delta z_{t-i} + \epsilon_{3t} \quad (8)$$

where θ_{11} and θ_{12} are the speeds of adjustment of Δy_t if y_{t-1} is above and below its long-run equilibrium, respectively. On the other hand, θ_{21} and θ_{22} represent the speeds of adjustment of Δx_t in the two regimes and θ_{31} and θ_{32} are, analogously, the speed of adjustment in the two regimes for Δz_t.

Nonlinear cointegration test results Table V reports the estimation results of the M-TAR model and the nonlinear cointegration tests for the producers and integrated firms in the oil industry. The null hypotheses of no cointegration and symmetric cointegration are both rejected for the two segments of the oil industry at all significance levels. This means that adjustments to the equilibrium are different across positive and negative errors.

Nonlinear error correction model Tables VI and VII report the estimation results of the nonlinear error correction models (equations (6), (7) and (8)) for the two segments of the oil industry. Given that for the segment producers (*expl&prod*) $|\rho_1| < |\rho_2|$ this means that the M-TAR model exhibits more momentum, that is, the adjustment is stronger in one direction than in the other direction. In particular, for this segment there is substantial adjustment to the long-run equilibrium when the returns of the segment producers are below this relation of equilibrium ($\Delta\hat{\varepsilon}_{t-1} < 0$) and less adjustment in the other direction ($\Delta\hat{\varepsilon}_{t-1} \geq 0$). The estimate coefficients of $M_t\Delta\hat{\varepsilon}_{t-1}$ and $(1 - M_t)\Delta\hat{\varepsilon}_{t-1}$ are 0.001 and -0.01, respectively (see Δ*expl&prod* column of Table VI). The first speed of adjustment is not statistically significant at any relevant significance level while the p-value of the second speed of adjustment is 0.133. The stock prices of the producers adjust more quickly to bad news than to good news, similar to the results of Koutmos (1998).

Moreover, since Δoil_{t-1} and $\Delta market_{t-1}$ are not statistically significant, oil and market returns do not Granger cause *expl&prod* returns. Looking to the second and third columns of Table VI, we observe that the results are analogous. Bad news impacts oil and market returns more quickly than good news.

Table VI shows that in the long run, the adjustment for oil price falls is faster for the three variables than for oil price increases. Strikingly, producers and the stock market do not seem to respond to short-run oil price changes, which might suggest that short-run effects are subsumed by long-run effects.

The results are different for integrated firms (*integ*) (see Table VII). The returns of segment petroleum refiners and the oil returns are only explained by their past values. Since $|\theta_{31}| = |\theta_{32}|$, the speed of adjustment of the market prices is of similar magnitude whether the prices of *integ* are above or below the long-run equilibrium.

Overall, the adjustment parameters for the producers indicate that when variables depart from their underlying equilibrium relationship, adjustment back to equilibrium is more rapid when oil prices decrease (below long run value), than when oil prices increase (above long run value).

B. Asymmetric Cointegration

In section III we have detected a possible nonlinear long-run relationship among oil exploration and producers, oil and stock market prices that has been confirmed by the existence of a non-linear cointegration relationship among them. Figures 1 and 2 also suggest there is a lagged co-movement among oil prices and, *expl&prod* and *integ* prices, in particular, for price falls. This empirical effect is not observed for the market prices, especially in the period between 2000 and 2003 (see Figure 1). This would suggest that in the long run *expl&prod* and *integ* prices tend to react asymmetrically to oil price shocks.

In order to confirm this empirical evidence observed from figures 1 and 2, we use a different concept of cointegration that distinguishes between positive and negative increments of oil price and allows us to determine which increments affect its long-run relationship with *expl&prod* and *integ*. To this end, we follow Schorderet (2003) and apply the concept of asymmetric cointegration. Let Y_t be a time series that can be decomposed into two partial sums, a positive (Y_t^+) and a negative (Y_t^-), such as:

$$Y_t^+ = \sum_{i=0}^{t-1} 1\{\Delta Y_{t-i} \geq 0\}\Delta Y_{t-i} \text{ and } Y_t^- = \sum_{i=0}^{t-1} 1\{\Delta Y_{t-i} < 0\}\Delta Y_{t-i}. \quad (9)$$

Y_{1t} and Y_{2t} are two $I(1)$ time series and define Y_{jt}^+ and Y_{jt}^- for $j = 1, 2$ according to equation (9). There is an asymmetric cointegration between Y_{1t} and Y_{2t} if there is a linear combination between Y_{jt}^+ and Y_{jt}^-

$$z_t = \beta_0 Y_{1t}^+ + \beta_1 Y_{1t}^- + \beta_2 Y_{2t}^+ + \beta_3 Y_{1t}^-, \quad (10)$$

such that z_t is stationary. The cointegrated vector must satisfy $\beta_0 \neq \beta_1$ or $\beta_2 \neq \beta_3$ (and β_0 or $\beta_1 \neq 0$ and β_2 or $\beta_3 \neq 0$). Assuming that one component of each series appears in the cointegration equation (10), we may write

$$z_{1t} = Y_{1t}^+ - \beta^+ Y_{2t}^+ \text{ or } z_{2t} = Y_{1t}^- - \beta^- Y_{2t}^-. \quad (11)$$

Given that the OLS estimators of the previous parameters are biased in finite samples, Schorderet (2003) proposes to estimate the following auxiliary regressions by OLS:

$$\xi_{1t} = Y_{1t}^- + \Delta Y_{1t}^+ - \beta^- Y_{2t}^- \text{ or } \xi_{2t} = Y_{1t}^+ + \Delta Y_{1t}^- - \beta^+ Y_{2t}^+. \quad (12)$$

The OLS estimators are in this case asymptotically normal (see also Lardic and Mignon, 2008).

Asymmetric cointegration test results In our particular case, we test for asymmetric cointegration between *expl&prod* and *oil*, and *integ* and *oil*, by estimating the following equations:

$$\begin{aligned} \text{expl\&prod}_t^- + \Delta\text{expl\&prod}_t^+ &= \alpha^- + \beta^- oil_t^- + \xi_{1t} \\ \text{expl\&prod}_t^+ + \Delta\text{expl\&prod}_t^- &= \alpha^+ + \beta^+ oil_t^+ + \xi_{2t} \end{aligned} \tag{13}$$

and

$$\begin{aligned} \text{integ}_t^- + \Delta\text{integ}_t^+ &= \theta^- + \psi^- oil_t^- + s_{1t} \\ \text{integ}_t^+ + \Delta\text{integ}_t^- &= \theta^+ + \psi^+ oil_t^+ + s_{2t}. \end{aligned} \tag{14}$$

There is asymmetric cointegration between *expl&prod* (*integ*) and oil prices if ξ_{1t} and/or ξ_{2t} (s_{1t} and/or s_{2t}) are stationary. We check this by applying the usual ADF tests to the residuals.

Table VIII reports the results of the ADF tests. Considering $\hat{\xi}_{1t}$, it appears that for the production firms of the oil industry, oil prices and *expl&prod* seem to be asymmetrically cointegrated. The same happens for the integrated firms since we reject the null hypothesis of unit root for the s_{1t} series of residuals. As for oil price increases, we cannot conclude there is asymmetric cointegration. Overall, falls in oil prices seem to affect *expl&prod* and *integ* prices in the long run.

V. Conclusion

Firm managers and investors of commodity dependent industries are concerned about how changes in the price of the main commodity potentially impact the value of the firm. It is thus paramount to gain insights into the long term economic relationship between these variables.

Our study analyzes whether the value of oil firms (producers and integrated firms) is related to the price of oil in the long run. The analysis is done using nonlinear cointegration models that account for the possibility of an asymmetric adjustment process to the long-run equilibrium. Our main empirical finding is that there are long-run asymmetric responses of firm value to oil price changes. The presence of nonlinear cointegration is confirmed under the momentum threshold autoregressive model which reveals asymmetries in the adjustment process. We find that the speed of adjustment is different depending whether the deviations are above or below the long term relation. The results show that the adjustment for oil producers is faster when there are drops in the price of oil, but we do not find a similar adjustment for integrated firms. Using the concept of asymmetric cointegration, we also confirm that negative increments of oil prices affect the long-run equilibrium between producer (integrated) firm prices and oil prices.

The asymmetric relationship of firm value in the long run is consistent with several explanations. First, with the option valuation approach. Firm value in the natural resources business is regarded as the value of an option on the main commodity. Works such as Pindyck (1990) assume that production permanently stops as soon as the price falls below extraction cost. When this occurs, the reserves which are not yet extracted are lost and the producers do not have the option to resume production in the future. Litzenberger and Rabinowitz (1995) refer that, in the case of some oil wells, a complete cessation of production can reduce the total recovery. The asymmetric relationship is a natural outcome of the asymmetric relationship between the value of the option and the value of underlying asset.

The results can also reflect the competitive structure of this industry. Factors such as the industrial structure, the substitutability between goods and the barriers to entry can enhance the market power of companies. Thus, firm value changes asymmetrically in the long run with oil price because firms can pass through oil price increases to customers.

Finally, we cannot disregard the hypothesis that the asymmetric relationship mirrors some irrational behavior by investors. A strand of literature has proved that investors' non-rational behavior originates mispricing of securities (Daniel et al., 1998, 2002).

Results highlight the need for hedging, because firm value is negatively affected by oil price falls in the long run. Overall, it not only suggests that firm managers should hedge to protect their value from falls in oil price, but that investors should also protect the value of their investment from oil price falls.

Moreover, the implications of these results are related with market inefficiency. The cointegration analysis characterizes the dynamic relation of the variables, and, as such, it is possible to use information from oil markets to predict trends in stock markets. Results suggest scope for arbitrage opportunities due to the presence of deviations from the long-run equilibrium, as well as different speeds of adjustment, i.e., a rapid adjustment to equilibrium values only when oil price falls. Conversely, when oil price increases, firm value seems to stay above the equilibrium relationship for a long time.

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Figures and Tables

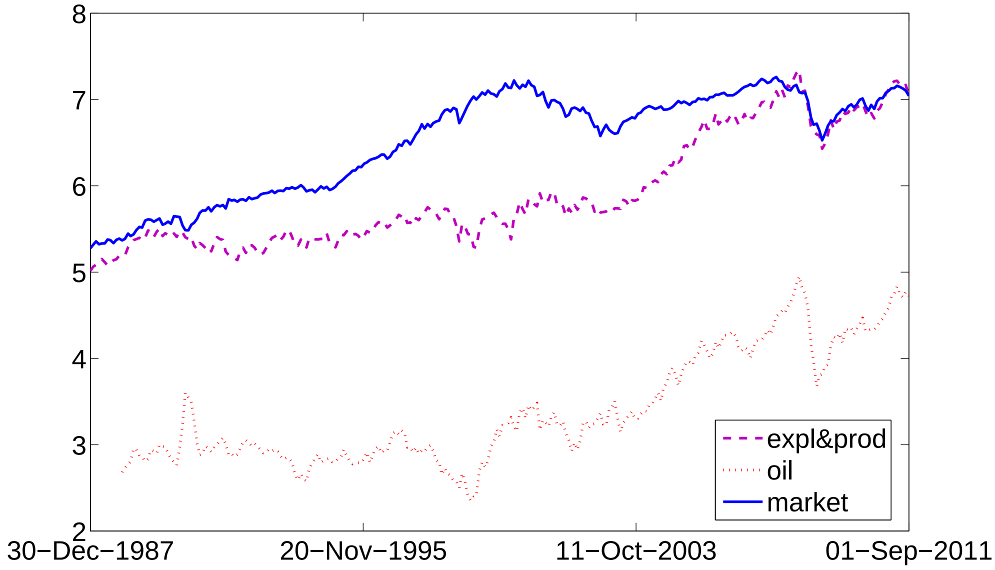

Figure 1. Time series of *expl&prod*, *market* and *oil* prices. The three series are in logarithms.

Table I
Summary statistics

This table presents the summary statistics of the returns of *expl&prod*, *integ*, *oil* and *market*. The sample period ranges from 1987:12 through 2011:08. By column, we report the mean, the standard deviation (SD), the kurtosis, the skewness and the Jarque-Bera test statistics and its p-value.

variables	mean	SD	skewness	kurtosis	Jarque-Bera	p-value
expl&prod	0.007	0.070	-0.136	4.320	20.550	0.000
integ	0.008	0.045	-0.038	3.956	10.260	0.006
oil	0.007	0.095	-0.359	5.393	68.797	0.000
market	0.006	0.044	-0.830	4.687	64.658	0.000

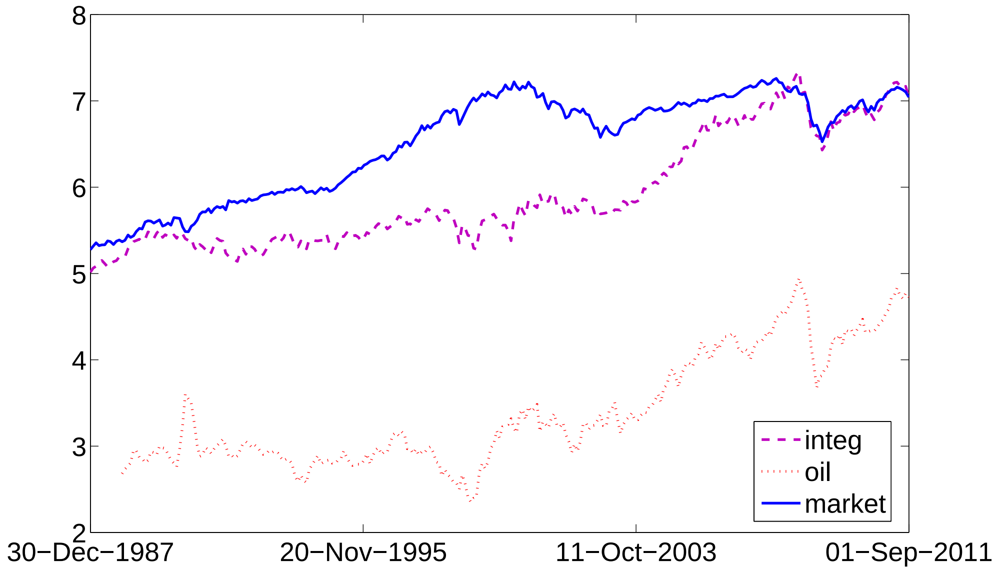

Figure 2. Time series of *integ*, *market* and *oil* prices. The three series are in logarithms.

Table II
Correlation coefficients

This table presents the correlations among the logarithms of the variables in levels: *expl&prod*, *oil* and *market*. The sample period ranges from 1987:12 through 2011:08.

variables	*expl&prod*	*integ*	*oil*	*market*
expl&prod	1.000			
integ	0.934	1.000		
oil	0.958	0.860	1.000	
market	0.705	0.897	0.600	1.000

Table III
Unit root tests on individual series

This table reports the results of the Augmented Dickey-Fuller test (ADF). The sample period ranges from 1987:12 through 2011:08. * (resp.**): Rejection of the null hypothesis at the 5% (resp. 1%) significance level. The three original series are in logarithms. The auxiliar regression of the test includes a constant and the number of lags (k) is 12.

	Series in logarithms	Series in first differences
variables	ADF(k)	ADF(k)
expl&prod	-0.141	-4.680**
integ	-0.951	-4.298**
oil	-0.222	-5.483**
market	-1.946	-4.307**

Table IV
Engle-Granger ADF cointegration tests

This table presents the results of the Augmented Dickey-Fuller test (ADF) on the residual series of equations ((1) and (2)). The sample period ranges from 1987:12 through 2011:08. * (resp.**): Rejection of the null hypothesis at the 5% (resp. 1%) significance level. The three original series are in logarithms. The auxiliar regression includes a constant and the k number of lags (k), those that are statistical significant.

Dependent variable of equation (3)	Engle-Granger ADF statistics	Cointegration
$y_t = expl\&prod_t$	-0.288	No
$y_t = integ_t$	-0.288	No

Table V
Enders-Siklos nonlinear cointegration tests

This table reports the results of the Enders-Siklos nonlinear cointegration tests using the M-TAR specification (4). The sample period ranges from 1987:12 through 2011:08. * (resp.**): Rejection of the null hypotheses at the 5% (resp. 1%) significance level. The critical values of Φ^* statistic are given in Table 1 of Enders and Siklos (2001). F indicates F-statistic for the null hypothesis of symmetric adjustment, $\rho_1 = \rho_2$. The values in parenthesis are the p-values.

	$H_0 : \rho_1 = \rho_2 = 0$	$H_0 : \rho_1 = \rho_2$
Dependent variable	M-TAR: Φ^*	M-TAR: F-test
residual changes of *expl&prod*	185.12**	360.37** (0.000)
residual changes of *integ*	172.00**	342.82** (0.000)

Table VI
M-TAR nonlinear error-correction models: *expl&prod*, *oil* and *market*

This table reports the estimation results of equations (6), (7) and (8)). The sample period ranges from 1987:12 through 2011:08. The values in parentheses are the p-values.

	Δexpl&prod$_t$	Δoil_t	$\Delta market_t$
$M_t\hat{\varepsilon}_{t-1}$	0.001 (0.891)	-0.003 (0.629)	-0.008 (0.062)
$(1-M_t)\hat{\varepsilon}_{t-1}$	-0.010 (0.133)	-0.027 (0.000)	-0.010 (0.023)
Δexpl&prod$_{t-1}$	-0.137 (0.016)	–	-0.068 (0.123)
Δoil_{t-1}	–	0.098 (0.016)	–
$\Delta market_{t-1}$	–	–	0.119 (0.086)
constant	0.030 (0.427)	0.087 (0.020)	0.060 (0.024)

Table VII
M-TAR nonlinear error-correction models: *integ*, *oil* and *market*

This table presents the estimation results of equations ((6), (7) and (8)). The sample period ranges from 1987:12 through 2011:08. The values in parentheses are the p-values.

	Δinteg$_t$	Δoil_t	$\Delta market_t$
$M_t\hat{\varepsilon}_{t-1}$	-0.003 (0.527)	-0.0001 (0.990)	-0.008 (0.069)
$(1-M_t)\hat{\varepsilon}_{t-1}$	-0.003 (0.521)	-0.0001 (0.990)	-0.008 (0.075)
Δinteg$_{t-1}$	-0.110 (0.112)	–	–
Δoil_{t-1}	–	0.179 (0.021)	–
$\Delta market_{t-1}$	–	–	0.131 (0.050)
constant	0.026 (0.398)	0.007 (0.910)	0.064 (0.028)

Table VIII
Asymmetric cointegration tests

This table presents the results of the ADF unit root tests on the residuals of equations (13) and (14). The sample period ranges from 1987:12 through 2011:08. * (resp.**): Rejection of the null hypotheses at the 5% (resp. 1%) significance level. The values in parenthesis are the p-values.

	ADF test on ξ_{1t}	ADF test on ξ_{2t}	ADF test on s_{1t}	ADF test on s_{2t}
expl&prod	-4.861** (0.000)	1.113 (0.995)	–	–
integ	–	–	-4.861** (0.000)	1.113 (0.953)