

Nonlinear Linkages between Oil and Stock Markets in Developed and Emerging Countries

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ABSTRACT

In this paper we study stock price adjustment dynamics in a nonlinear framework while examining their relationship with the oil market. Comparing four countries (USA, France, Mexico and the Philippines), we identify several significant findings. First, we highlight some evidence of considerable linkages between stock and oil markets and we show significant long-run relationships between these markets. Second, using nonlinear cointegration techniques, we propose an on/off nonlinear model to investigate time dependency and reproduce the linkages between the oil and stock markets. More interestingly, we identify different regimes for stock-oil price deviations and show a nonlinear mean-reverting mechanism which is activated by regime with an adjustment speed that increases according to price deviations toward the equilibrium.

JEL classification: C22, E32, G15

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I. INTRODUCTION

Understanding the behavior of stock returns and identifying the factors that affect their dynamics is crucial to making efficient financial decisions, particularly in periods of international financial crisis. Although there is already a plethora of empirical studies investigating asset pricing, the nature and number of factors that determine stock return structures remain elusive. As the price of oil has changed dramatically over recent years with sequences of considerable fluctuation, now is an excellent moment to add to existing research on its impact on stock market returns. The use of oil price fluctuations as a factor affecting stock prices can be justified by the fact that the fundamental value of a stock is equal in theory to the discounted sum of expected future cash flows. The latter are affected by macroeconomic events that may possibly be influenced by oil shocks. Thus, oil price changes may influence stock prices.

There have been a large number of studies on linkages between oil prices and economic activity in the literature. Most of these studies have established significant effects of oil price changes on economic variables for a number of developed and emerging countries (Cunado and Perez de Garcia, 2005; Balaz and Londarev, 2006; Gronwald, 2008; Cologni and Manera, 2008; and Kilian, 2008). Furthermore, some papers have shown that the link between oil and economic activity is not entirely linear (Hamilton, 2003; Zhang, 2008; Lardic and Mignon, 2006, 2008; Cologni and Manera, 2009). In sharp contrast to this large volume of studies investigating the links between oil prices and economic activity, there has been relatively little work on the relationship between oil price changes and stock market returns. Furthermore, most of these studies have focused on just a few industrial countries (the USA, Canada, Europe and Japan). Few empirical investigations have been carried out on emerging stock markets, and the few that exist have mainly focused on the short-term interaction between energy price shocks and stock markets.

The pioneering empirical investigation of the question by Jones and Kaul (1996) tests the responses of international stock market returns (Canada, UK, Japan and the USA) to oil price changes. Using a standard discounted dividend model, the authors find that for the USA and Canada this reaction can be accounted for entirely by the impact of the oil shocks on cash-flows. The results for Japan and the UK were inconclusive. Based on a VAR model, Huang et al. (1996) find no evidence of a relationship between oil prices and market returns such as the S&P500. In contrast, Sadorsky (1999) applies a VAR model with GARCH effects to US monthly data and identifies a significant relationship between oil price changes and aggregate stock returns in the USA. In particular, he shows that oil prices have asymmetric effects, with positive oil shocks having a greater impact on stock returns and economic activity than negative oil price shocks. Relying on nonlinear causality tests, Ciner (2001) provides evidence of a nonlinear impact of oil shocks on stock index returns in the USA. Park and Ratti (2008) argue that oil prices have a negative impact on stock returns in the USA and in twelve European countries, while for Norway, an oil exporting country, they show a positive response of stock market to oil price rise. More recently, Apergis and Miller (2009) examines whether structural oil-market shocks affect stock prices in eight developed countries. Employing different econometric tools, the authors conclude that developed stock markets do not react significantly to oil price changes.

Some recent papers have focused on major European, Asian and Latin American emerging markets. The main findings show a significant short-run link between oil price changes and emerging stock prices. Based on a VAR model, Papapetrou (2001) finds a significant relationship between oil price changes and stock markets in Greece. Basher and Sadorsky (2006) reach the same conclusion for other emerging stock markets using an international multifactor model. Maghyreh (2004), however, investigates the relationships between oil and stock market prices in 22 emerging markets and finds no impact on stock returns in these countries. Finally, Nandha and Hammoudeh (2007) examine the short-run reaction of stock markets to oil price shocks in the Asia-Pacific region. They find the Philippines and South Korean stock markets to be oil-sensitive when the price is expressed in local currency only. However, the authors conclude that none of the countries they studied present sensitivity to oil prices expressed in US dollars, regardless of whether the oil market is up or down.

Overall, the results from the available studies on the relationship between oil and stock returns are inconclusive. This could be due to weaknesses in the linear econometric techniques used in most previous studies as linear methods are not powerful enough to detect asymmetries and nonlinear linkages between oil and stock market returns. However, as mentioned above, recent papers have tended to argue that there is a relatively asymmetric relationship between oil price and economic activity. This suggests that asymmetric linkages between oil prices and the stock market could be disclosed using linear modeling. This article extends the understanding of the relationship between oil prices and the stock market by testing for nonlinear linkages in addition to linear linkages for both the developed and emerging markets. Formally, we use a particular class of nonlinear cointegration models, namely, the Switching Transition Error Correction models (STECM) developed by Van Dijk, Teräsvirta and Franses (2002), among others. To investigate the relationship between oil prices and stock markets, this econometric technique is more robust than the traditional linear cointegration technique.

The paper is organized as follows. The following section briefly presents the STECM. Section III discusses our empirical results and a final section concludes the paper.

II. NONLINEAR ADJUSTMENTS FOR OIL AND STOCK PRICES

Linear cointegration theory stipulates that although two variables may undergo some short-term disruptions, they can develop a stable relationship converging toward long-term equilibrium (Engle and Granger, 1987). Formally, let X_t and Y_t be two variables that are integrated of one order, noted $I(1)$, here X_t is the oil price and Y_t the market index). In the long term, if it is possible to find a linear combination which is stationary between these two variables, noted z_t , then X_t and Y_t are linearly cointegrated and the long-run cointegration relationship is given as follows:

$$z_t = Y_t - \theta_0 - \theta_1 X_t \quad (1)$$

where z_t is the error-correction term or the residual of the cointegration relationship; θ_0 and θ_1 are the parameters of the cointegration relationship.

If the two variables are linearly cointegrated, the short-run dynamics of stock to oil prices can be checked using the following Linear Error-Correction Model (LECM):¹

$$\Delta Y_t = \alpha_0 + \rho z_{t-1} + \sum_{i=1}^p \alpha_i \Delta Y_{t-i} + \sum_{j=1}^p \beta_j \Delta X_{t-j} + \varepsilon_t \quad (2)$$

where ρ is the linear adjustment term that brings the stock price back toward the equilibrium.

Nevertheless, linear techniques limit the adjustment between oil and stock prices to being symmetric, linear and continuous, and therefore the adjustment speed to being time-invariant. To take these limitations into account, we extend the linear model to the nonlinear one. More precisely, we employ a threshold cointegration model with two regimes: the STECM. In the first regime, no adjustment occurs and deviations from the equilibrium can last a very long time, be divergent and have a unit root, even though they do not necessarily follow a random walk. In the second regime, adjustment is more active and prices are mean-reverting, with an adjustment speed that increases with the size of the disequilibrium, and deviations from the equilibrium may approach a white noise. Overall, the deviations follow a nonlinear process that is mean-reverting with a convergence speed that varies directly with the extent of deviations from the equilibrium.

Formally, threshold cointegration models are introduced by Balke and Fomby (1997). Anderson (1997) proposes an extension of these models that takes into account gradual transitions rather than abrupt ones, as defined by the STECM that was developed more recently by Van Dijk et al. (2002). These models were used in particular to reproduce the financial asset adjustment dynamics toward the equilibrium (Anderson, 1997; and Van Dijk et al., 2002). The STECMs include the exponential STECM (ESTECCM) that also defines different regimes while specifying the adjustment that takes place during each period. Its advantage is to define an adjustment speed that varies with the size of the deviations. Indeed, when these deviations (z_t) exceed a certain threshold, the adjustment becomes active and the price is mean-reverting toward equilibrium. Formally, the ESTECCM is defined as follows:

$$\Delta Y_t = \alpha_0 + \rho_1 z_{t-1} + \rho_2 z_{t-1} \times F(\gamma, c, z_{t-d}) + \sum_{i=1}^p \alpha_i \Delta Y_{t-i} + \sum_{j=1}^p \beta_j \Delta X_{t-j} + \varepsilon_t \quad (3)$$

where $F(\gamma, c, z_{t-d}) = 1 - \exp\left[-\gamma(z_{t-d} - c)^2\right]$, F is the transition function, $\gamma > 0$ and c are respectively the transition speed and the threshold parameter, z_{t-d} is the transition variable, while d is the delay parameter that defines the transition variable and $\varepsilon_t \rightarrow N(0, \sigma^2)$.

This model describes two different dynamics corresponding to the extreme values of F (0 and 1) and an intermediate state continuum for the other values of F . The central regime is defined when prices are close to the equilibrium, corresponding to:

$$\Delta Y_t = \alpha_0 + \rho_1 z_{t-1} + \sum_{i=1}^p \alpha_i \Delta Y_{t-i} + \sum_{j=1}^p \beta_j \Delta X_{t-j} + \varepsilon_t \quad (4)$$

The extreme regimes are defined as follows:

$$\Delta Y_t = \alpha_0 + (\rho_1 + \rho_2) z_{t-1} + \sum_{i=1}^p \alpha_i \Delta Y_{t-i} + \sum_{j=1}^p \beta_j \Delta X_{t-j} + \varepsilon_t \quad (5)$$

ρ_1 and ρ_2 are the most significant parameters, specifying the price adjustment dynamics and defining its convergence speed toward the equilibrium. Indeed, even if ρ_1 is positive, ρ_2 and $(\rho_1 + \rho_2)$ should be negative and statistically significant to validate a nonlinear mean reversion in stock prices. This implies that for a minor disequilibrium, price deviations would diverge from the equilibrium and would be characterized by a unit root or explosive behavior, but for large deviations, the adjustment process would be mean-reverting.

The STECM modeling is described in Van Dijk et al. (2002). We first check the cointegration hypothesis in a linear framework. Second, we test the linearity hypothesis. Finally, if linearity is rejected, we estimate the ESTECM by the Nonlinear Least Squares (NLS).

III. EMPIRICAL RESULTS

A. The Data

We used monthly prices over the period December 1987 – March 2008. We chose to investigate the link between oil prices and stock markets in two developed markets (the USA and France) and two emerging markets (Mexico and the Philippines). The stock indexes come from Morgan Stanley Capital International (MSCI) while the oil price series was obtained from the Dow Jones & Company database. Stock indexes are closing prices and all price series are converted into US dollars and transformed into logarithms to reduce their variance

B. Linear Cointegration Tests

In order to test for linear cointegration between oil and stock prices, we need to check for the stationarity of z_t (equation (1)). We began by testing the integration order for all the series in the study. Applying two tests, the ADF test of Dickey and Fuller (1981) and the PP test of Phillips and Perron (1988), we show that all series are $I(1)$.³ Second, we test the null hypothesis of non-cointegration and our findings, based on ADF and PP tests, do not reject the linear cointegration hypothesis for all the countries either at 5% or 10%, implying that oil and stock markets are at least linearly linked (Table 1). However, care should be taken in the interpretation of these results since these tests are not powerful enough for series that are generated by nonlinear processes, as Taylor et al. (2001) pointed out. Indeed, these tests are based on linear specifications that are not very robust to the possible asymmetry and nonlinearity characterizing price dynamics.

In line with Van Dijk et al. (2002), we propose extending our study to the nonlinear framework while testing for a nonlinear cointegration relationship.

Before moving to nonlinear tests, we report the descriptive statistics of oil and stock returns in Table 2. We show the rejection of asymmetry and normality for all countries. This result and the negativity of skewness for all stock indexes may suggest some nonlinearities in stock and oil price dynamics. We also report the correlation matrix (Table 3) that shows two interesting remarks. First, a negative correlation between oil and stock returns indicates that an increase in oil price yields a decrease in stock returns. Second, this correlation is higher for developed countries, suggesting that the latter are more dependent on the oil industry than emerging countries.

To investigate the changes in the relationship between oil and stock prices, we compute the dynamic bilateral correlations between oil and stock prices. Our findings, as suggested by Figure 1 for the US market, show that the oil to stock price correlation appeared systematically non cyclical before the crisis, but some evidence of positive correlations are captured after the crisis.⁴ Such asymmetry in the interdependence between oil and stock prices may escape linear modeling and requires the use of nonlinear models.

Table 1
Linear cointegration test

	France	USA	Mexico	Philippines
ADF	-3.91*	-3.12*	-3.99*	-3.74*

Note: (*) denotes the rejection of non-cointegration hypothesis.

Table 2
Descriptive statistics of oil and stock returns

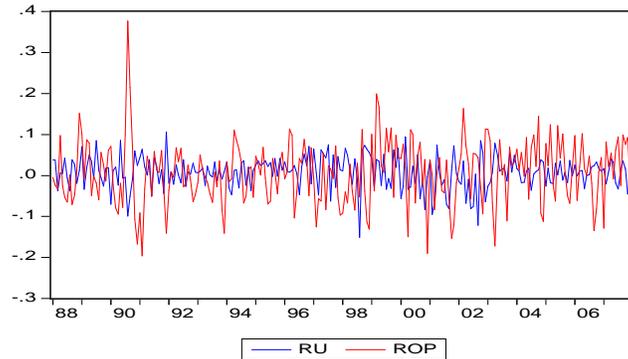
	France	Mexico	Oil	Philippines	USA
Mean	0.007	0.017	0.007	0.004	0.006
Std. Dev.	0.054	0.093	0.076	0.092	0.039
Skewness	-0.316	-0.948	0.281	-0.058	-0.543
Kurtosis	3.97	6.18	4.65	4.81	3.99
JB(p-value)	13.6(0.0)	139.4(0.0)	31.0(0.0)	33.45(0.0)	21.89(0.0)

Table 3
Correlation matrix

	RU	RPH	ROP	RMX	RF
RU	1.00	0.38	-0.21	0.50	0.61
RPH		1.00	-0.11	0.30	0.26
ROP			1.00	-0.03	-0.13
RMX				1.00	0.35
RF					1.00

Note: RU, RPH, RMX, RF and ROP respectively designate the US, Philippine, Mexican and French stock returns and oil returns.

Figure 1
Dynamic distribution of oil and US stock returns



C. Nonlinear Adjustment Tests

To check for linearity, we apply the nonlinear adjustment tests developed by Luukkonen and Saikkonen (1988) and discussed in Teräsvirta (1994). The main idea of these tests is to check the null hypothesis of linearity (equation (2)) against its nonlinear alternative (equation (3)).

Thus, in practice, we first specify the LECM and determine its lag number using the Information Criteria (AIC), Ljung-Box (1978) tests and the autocorrelation function. These specification tests suggest $p = 2$ for France, $p = 1$ for the Philippines and $p = 0$ for the USA and Mexico as the optimal lag. Secondly, we test the linearity hypothesis by testing the null hypothesis of LECM against its ESTECM counterpart. The linearity hypothesis is tested for several values of d . We supposed a maximal dependence of six months and we considered $d \in [1, 2, 3, 4, 5, 6]$ as plausible values of the delay parameter (d).

Among the linearity tests, we apply Lagrange Multiplier tests which follow a standard χ^2 under H_0 . In particular, we applied the LM_4 test that is distributed as $\chi^2(4(p + 1))$. Table 4 shows that linearity is rejected for several plausible values of d . This rejection is even stronger for $d = 1$ for Mexico and the Philippines, for $d = 2$ for France and for $d = 4$ for the USA.

This implies that the stock price adjustment for all the countries under consideration is nonlinear and that their dynamics are nonlinearly mean-reverting toward the equilibrium. The rejection of the linear adjustment implies a rejection of the hypothesis according to which the adjustment is symmetric and linear. Moreover, the acceptance of nonlinearity indicates evidence of an asymmetric cointegration relationship between oil and stock prices, suggesting that the linkages between these two variables are time-varying and strongly activated only when prices significantly rise or fall.

Finally, we use the ESTECM to specify the nonlinear mean reversion in stock prices.

Table 4
Linearity tests (p-values)

d	LM Statistics	France	USA	Mexico	Philippines
d = 1	LM ₄	0.01	0.02	0.02*	0.00
d = 2	LM ₄	0.00*	0.10	0.05	0.07
d = 3	LM ₄	0.04	0.07	0.15	0.13
d = 4	LM ₄	0.13	0.00*	0.29	0.28
d = 5	LM ₄	0.10	0.31	0.32	0.42
d = 6	LM ₄	0.23	0.73	0.42	0.62

Note: (*) designates the optimal value for which linearity is strongly rejected.

Table 5
ESTECCM estimation results

Coefficients	France	USA	Mexico	Philippines
Model	ESTECCM (2,2)	ESTECCM (0,4)	ESTECCM (0,1)	ESTECCM (1,1)
α_0	0.01* (2.8)	0.01* (3.5)	0.01** (1.9)	-0.01 (-0.7)
λ_1	0.16** (1.8)	-0.06* (-2.5)	-0.21* (-2.3)	0.13** (1.7)
α_1	-0.03 (-0.5)	-	-	0.22* (3.4)
α_2	-0.11** (-1.79)	-	-	-
β_1	-0.06** (-1.84)	-0.09* (-2.8)	-0.17* (-2.2)	-
λ_2	-0.18* (-2.01)	-0.08* (-2.9)	-0.18** (-1.91)	-0.16* (-2.2)
γ	130.8* (7.71)	10.3* (10.2)	5.3* (6.0)	6.3* (10.1)
c	-0.23* (-13.5)	0.48* (11.0)	-0.27* (-1.99)	0.46* (5.8)
ADF^a	-10.5	-11.6	-9.8	-10.2
ARCH^b	0.90	0.65	0.02	0.68
RNL^c	0.54	0.44	0.13	0.48
$\lambda_1 + \lambda_2$	-0.02	-0.14	-0.39	-0.03

Note: (*) and (**) respectively designate the statistical significance at 5% and 10%. (a), (b) and (c) respectively designate the p-values of the ADF, ARCH and Remaining Nonlinearity Tests. Values between brackets are the t-ratio.

D. ESTECCM Estimation Results

We estimated an ESTECCM(2,2) ESTECCM(0,4), ESTECCM(0,1) and ESTECCM(1,1) for France, the USA, Mexico and the Philippines, respectively. This procedure enabled us to estimate these models through the NLS method in several steps. Overall, our empirical results reported in Table 5 suggest a number of significant conclusions. First, oil prices significantly and negatively affect three stock markets: France, the USA and Mexico, confirming the negative correlation suggested above and indicating evidence

of significant linkages between the oil and stock markets. Second, while the French market shows negative autoregressive parameters, the US and Mexican markets depend far more on oil than on their previous tendencies, implying some also significant temporal dependence in the price dynamics of these markets. Third, the negativity and significance of the second adjustment term imply strong evidence of nonlinear mean reversion between oil and stock markets. Indeed, oil and stock markets may deviate in the first regime and stock market deviations may persist, remain uncorrected and away from equilibrium, but when deviations become higher and exceed a certain threshold, a nonlinear mean reversion is activated. Moreover, $(\lambda_1 + \lambda_2)$ is negative, confirming a nonlinear mean-reversion in the stock prices and suggesting that stock prices react asymmetrically to oil market shocks.

Fourth, the estimation of transition functions indicates significant coefficients, confirming the choice of the exponential function to reproduce the relationship and the adjustment between oil and stock markets. We identified different regimes: the first one defines a central regime in which price deviations are near unit root and convergence toward oil-stock price equilibrium relationship is not activated. In this regime, called also a “pure chartist regime”, stock prices are essentially governed by their previous tendencies. The second regime corresponds to the upper regimes, for which stock prices are mean-reverting toward oil price. In this “oil market follower regime”, the adjustment is activated more strongly and integration between oil and stock markets is statistically very significant.

Figure 2
Estimated transition functions

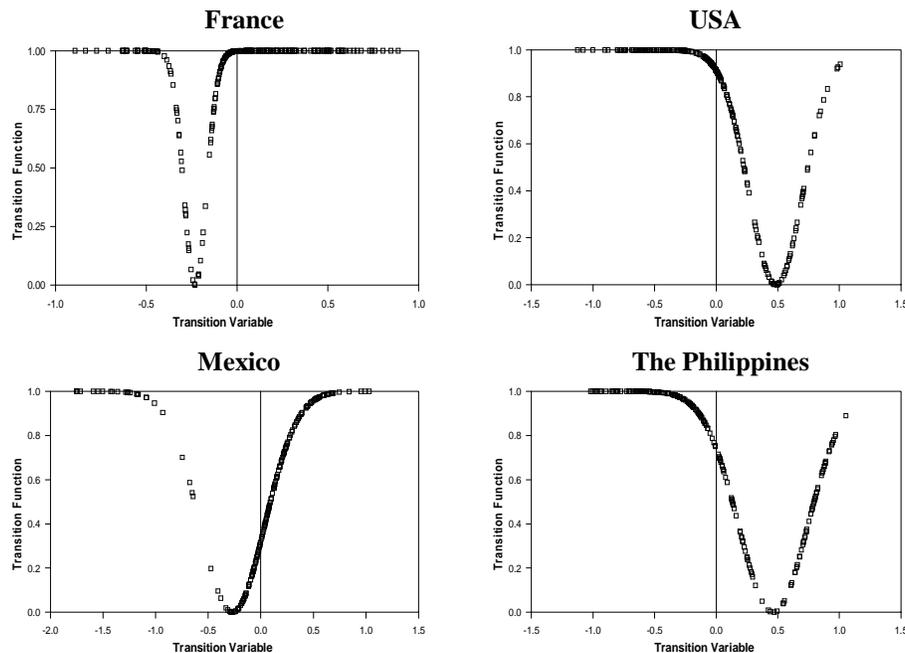
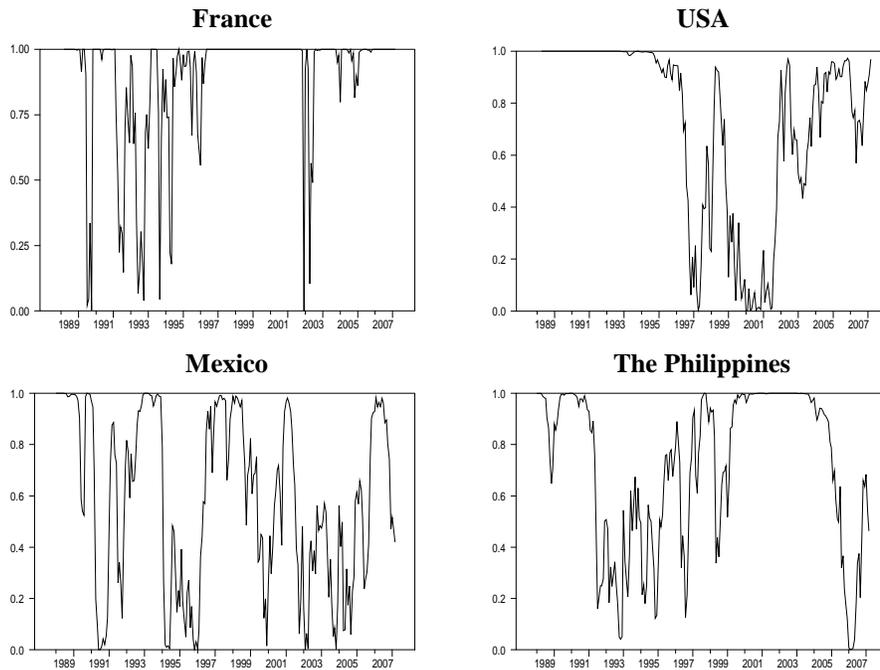


Figure 3
Time varying estimated transition functions



The estimation of the transition speed shows more rapid transition for the developed countries, confirming the greater dependence of their markets to oil prices. To illustrate these different regimes more explicitly, we plotted the estimated transition functions according to the transition variable (Figure 2), enabling us to reproduce the stock price dynamic and the relationship between oil and stock prices in each regime. For all indexes, the transition function reaches unity, implying that the oil-stock price relationship is often activated and that both markets are closely linked. We also noted that the adjustment speed of stock prices indicates that reversion increases with the size of price deviations from the equilibrium, showing that the higher the price deviations, the more strongly mean reversion is activated. While reproducing the estimated transition functions over time (Figure 3), we noted the high variability of the transition, suggesting that the adjustment is variable and that a time-varying correction mechanism between these markets is activated after each shock occurring in the oil market. This implies that stock prices may undergo some short-term disruptions, but they nonetheless share some similarities with oil market properties in the long term. Oil prices may thus forge a steady relationship with the stock market, converging toward an equilibrium for which the adjustment dynamic is nonlinear.

IV. CONCLUSION

In this paper, we studied the stock price adjustment hypothesis regarding its relationship with the oil market in a nonlinear framework. Our findings show evidence of a significant nonlinear cointegration relationship between the oil and stock markets in developed and emerging markets. In particular, the ESTECM model seems a useful tool for characterizing the oil-stock price relationship. It enables us to identify different regimes: a “pure chartist regime” for which the stock price adjustment is governed more by its previous tendencies and an “oil market follower regime” with a more significantly activated adjustment between oil and stock prices. Overall, stock price is nonlinearly mean-reverting toward the oil market equilibrium, with an adjustment speed that increases according to the size of the disequilibrium. These results are important as the use of such an on/off cointegration relationship between oil and stock markets could help investors to decide on their investments in the oil and/or stock markets according to the activation or not of this relationship. To take this research further, it would be interesting to extend the study to a larger group of developed and emerging countries, and to apply these nonlinear modeling techniques to forecast the reaction of stock markets to oil market shocks.

ENDNOTES

1. See Anoruo and Mustafa (2007) for a recent survey on papers investigating the link between oil prices and stock markets using linear cointegration and ECMs.
3. The results of unit root tests may be supplied on request to the corresponding author.
4. We have omitted the results for the other indexes to save space.

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