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Modelling oil price expectations: evidence from survey data

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Abstract – Using Consensus Forecast survey data on WTI oil price expectations for three and twelve month horizons over the period November 1989 – December 2008, we find that the rational expectation hypothesis is rejected and that none of the traditional extrapolative, regressive and adaptive processes fits the data. We suggest a mixed expectation model defined as a linear combination of these traditional processes, which we interpret as the aggregation of individual mixing behavior and of heterogenous groups of agents using simple processes. This approach is consistent with the economically rational expectations theory. We show that the target price included in the regressive component of this model depends on macroeconomic fundamentals whose effects are subject to structural changes. The estimation results led to validate the mixed expectational model for the two horizons.

KEYWORDS: **expectations formation, oil price**

CLASSIFICATION: **D84, G14, Q43**

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1. Introduction

Oil market shocks are among the main impulse shocks introduced in macroeconomic models to study the time path of the adjustment towards equilibrium (Garratt and Hall, 1997; Cologni and Manera, 2008). These shocks take the form of events such as sudden inventory changes, OPEC's pricing arrangements, conflicts, drilling field discoveries, or credibility of OPEC's intervention in a target zone model (Hammoudeh, 1996). They affect oil prices through oil price expectations (Hawdon, 1987, 1989; Rauscher, 1988; Hammoudeh and Madan, 1995) and through changes in the fundamentals (Hawdon, 1989). Focusing on the latter issue, oil market shocks can indeed alter supply and demand on different markets in the economy (Wirl, 1991); especially, a widespread literature has shown that oil price shocks affect output and inflation (Hamilton, 1983; Cunado and Perez de Garcia, 2005).

Studies concerned by the oil price expectations channel are, as for them, surprisingly scarce, and the processes that govern these expectations remain widely unknown. Indeed, literature deals with oil price expectations implicitly, that is, by focusing on oil future demand prospects (Cooper, 2003; Gately and Huntington, 2002) or on oil supply based on an optimization model of exploration and extraction behavior (Walls, 1992; Rao, 2000). However, a complete understanding of the oil price movements requires to knowing how oil price expectations are formed. The mainstream approach based on the rational expectation hypothesis appears to be inconclusive; for example, Moosa and Al-Loughani (1994) find that futures prices on the WTI appear to be inefficient predictors of spot prices, and that the time-varying risk-premium hypothesis tested using a GARCH-M framework in not capable of explaining this result, leaving unsolved the question of whether or not expectations are rational. In fact, efficiency tests require a joint hypothesis in the representation of rational expectations and of the risk premium, and this joint hypothesis arises because expectations are not observable.

One way of solving this problem is to use financial market price survey data. Numerous studies based on such data have attempted to model expected prices in various markets (exchange rates, stock prices, commodity prices, interest rates). To our knowledge, no such literature is devoted to oil price expectations except the study by MacDonald and Marsh (1993). Using Consensus Economics (CE) aggregated and disaggregated survey data on 3-month ahead WTI oil price expectations of experts from G7 countries, the authors show that the rational expectation hypothesis is strongly rejected both on aggregated and individual data whatever the respondent's country. Estimation of each of the three traditional extrapolative, adaptive and regressive expectation processes led the authors to suggest that the choice between these processes depends on countries and individuals. Using aggregated data (within or all countries) the adaptive and extrapolative models partially fit the data while the regressive model is not relevant. Nevertheless, the aggregate analyses covers the period October 1989 - March 1991 (18 months), which is too short a sample to yield accurate inferences, and implies that the results are too much impacted by the Gulf crisis to exhibit a general expectational behavior as proven by the rejection of all processes when Gulf crisis-correcting dummies are introduced.

A time series approach over an expanded period would allow for treating the time varying target price endogenously contrary to the fixed target introduced by MacDonald and Marsh (1993) and, at the same time, to check for the stability of expectation formation process. Moreover it seems interesting to investigate the expectational models for different time horizons, namely the 3 and 12-month horizons considered by CE since the beginning of the survey. Finally, the heterogeneity evidenced by the authors concerning the selection of the forecast model justifies that an expectation model combining the three traditional processes be tested on the aggregate level. The point in analyzing aggregate data is that it may be viewed as a proxy of the market expectation, and this proxy is all the more reliable as individual measurement errors tend to offset each other. Last but not least, it is important to place the expectation formation analysis in relation to a theoretical framework. The *economically rational expectations* framework first introduced by Feige and Pearce (1976) is appropriate to study the formation of expectations in the extent that it is based on a cost-and-advantage analysis of information. In this framework, agents collect and use information until equality is reached between the unit cost of information and the marginal gain due to the use of this information. This provides a general approach to understand the different expectation processes from the naive process to the Muthian rationality through the traditional extrapolative, regressive and adaptive processes and any combination of them. Using aggregated data from the same survey over the period November 1989 – December 2008, this paper aims to contribute to the issues discussed above.

One interesting feature of studying expectation formation in the light of survey data is to compare with oil price forecast models to assess whether or not the CE experts behave in accordance to the forecasting techniques suggested in the literature. Numerous studies using a variety of methods find that among the basic predictor variables of oil prices are the excess production capacity (Ye, Ziren and Shore, 2006) and, for earlier periods, the short term component of the OECD inventory data (Ye, Ziren and Shore, 2008). Ye, Ziren and Blumberg (2009) show that these variables can be successfully completed with the cumulative excess production capacity (ratchet effect) reflecting the changing behaviors on both demand and supply. Using belief networks approach, Abramson and Finizza (1991) show that world GDP growth and supply and demand of crude oil are influential variables for forecasting crude oil price for 1990. Kaufmann, Dees, Karadeloglou and Sanchez (2004) find that the real oil price is explained by OPEC capacity utilization and quotas, among other variables. This suggests that inflation can also be considered as a predictor of the change in nominal oil price. Many authors report the forecasting performance of the futures oil market prices (Coimbra and Esteves, 2004; Abosedra, 2005; Coppola, 2008), whereas world economic growth expectations affect the futures prices and therefore are an indirect predictor of oil prices (Coimbra and Esteves, 2004). However, using an appropriate decomposition of the data generating process of the WTI oil price, Cuaresma, Jumah and Karbuz (2009) suggest that forecasting the fundamentals partially predicts oil price, and that the influence of short term factors must also be taken into account.[1] Overall, we show that most of the predictor variables identified by the forecast models are used by the respondents to CE surveys.

The paper is organized as follows. Section 2 examines the microfoundations of expectational processes in the economically rational expectations framework. Section 3

[1] Engle and Manganelli (2004) and Huang, Yu, Fabozzi and Fukushima (2009) propose specific models to forecast oil market risk measured by a Value-at-Risk. These contributions are complementary to those relating to forecasts in the oil market returns since, on a financial point of view, purchases and sales in the oil market are driven by the expected return and the risk associated to them.

presents the CE survey data on oil price expectations used to test the processes. On the basis of these data, section 4 shows that the rational expectations hypothesis on oil price is rejected. This result leaving open the question of how expectations are formed, section 5 discusses the hypothesis of a mixed process based on the traditional extrapolative, adaptive and regressive processes. Since the latter process includes an unknown target variable which is to be modeled, section 6 searches the appropriate target specification that is found to be characterized by structural breaks. The estimation of the mixed process is then presented in section 7. Section 8 provides concluding remarks.

2. Theoretical aspects of the expectation behavior

When information is costless and the "true" data generating process of a market price is known, the forecast model is optimal in the sense that the forecast error variance is minimum. This implies that expectations are rational. For instance, if the change in the price is represented as a sequence of stochastic observed shocks, the adaptive process is optimal (Muth, 1960). If, alternatively, the change in the price has an autoregressive representation, the optimal expectation process is of the extrapolative form (Baillie and MacMahon, 1992). If it exhibits a mean-reversion dynamics, the optimal expectation process is of the regressive form (Holden, Peel and Thomson, 1995). Of course, one can consider a complex generating process defined as some combination of the preceding simple processes, and it can be shown that the optimal expectation process in this case is a mixed process. Nevertheless, empirical studies based on survey data reject the null of unbiasedness (MacDonald, 2000 for exchange rates, Gramlich (1983) for good prices and Pearce (1984) for stock prices) and also the one of homogeneity (MacDonald and Marsh, 1996, for foreign exchange rates, Cukierman and Wachtel, 1979, for good prices). We will discuss in section 4 these issues using oil price expectations data. These results, which clearly contradict the rational expectation hypothesis (REH), may be interpreted as being due to an unachieved learning process (Frankel and Froot, 1987), or to a 'peso effect' (Kaminsky, 1993) or to voluntarily unused information due to information costs (Feige and Pearce, 1976). However, there is in the litterature no empirical study using survey data known to have evidenced some improvement over time in the forecast accuracy of a market price, and this seems to indicate that no significant learning effect operates at the aggregate level. On the other hand, a peso effect may generate expectation bias but it implies homogeneity, which is not compatible with the empirical results mentioned above. In fact, bias and heterogeneity may both be explained by the existence of informational costs. This is in line with the economically rational expectation framework introduced by Feige and Pearce (1976), where the expectation process chosen by the agents at any time results from a cost-and-advantage analysis of information. Baghestani (1992) distinguishes a weak form and a strong form of economically rational expectations of US inflation defined as an autoregressive process and a more flexible process including macroeconomic variables, respectively. By comparing the forecast error of the household inflation survey forecasts with the forecast errors of the two benchmark processes, the author finds that these expectations are more closely related to the weak (strong) form during periods with low (high) inflation volatility. Although the author does not attempt to model the expectation behavior, his results suggest that the set of information that conditions expectations may change over time following the state of the economy. This variability of the environment is also a central issue in Sethi and Franke (1995) who distinguish a group of rational agents who optimize with respect to informational costs and a group of non-optimizer (adaptive) agents who use costless information. The authors find that the proportion of rational agents increases when economic uncertainty rises whereas the adaptive agents are favoured in a stable environment. In a theoretical approach, Crettez and Michel (1992) show that the costless adaptive expectation converges towards the costly rational expectation so that the adaptive process corresponds to an economically rational choice.

We now sketch the economically rational expectation theory. Let I_{it}^{j} be a measurable amount of information of type i (i=1,2,…,n)[2] that agent *j* may use to forecast at time t and c_{it}^{j} the price of collecting and processing a unit of this information supported by this agent. Assuming constant returns to scale, c_{it}^{j} is a marginal cost. Let f be a twice continuously differentiable function relating the information inputs I_{it}^{j} to the agent's expected quadratic forecast error. We assume:

$$E_t(\tilde{p}_{t,\tau}^{j} - p_{t+\tau})^2 = f(I_{1t}^{j},...,I_{it}^{j},...I_{nt}^{j}) \qquad f_i < 0, \quad f_{ii} > 0 \quad i = 1,...n \tag{1}$$

where p_t and $\tilde{p}_{t,\tau}^{j}$ are the logarithm at time *t* of the oil price and of the expected oil price for the horizon τ by agent *j*, respectively.[3]

The sign of the first derivative of f means that the more the agent collects information the more (s)he expects to reduce the squared forecast error through some underlying expectation process. A zero value for f_i would mean that the information i has been excluded from the set of relevant information even if it is costless. The sign of the second derivative says that the marginal efficiency of the information decreases as I_{it}^{j} increases. To determine the optimal amount of each type of relevant information, the forecaster minimizes at any time the following total cost:

$$C_t^j = \pi_t^j f(I_{1t}^{j}, I_{2t}^{j},...I_{nt}^{j}) + \sum_{i=1}^{n} c_{it}^{j} I_{it}^{j}, \tag{2}$$

where $\pi_t^j > 0$ is the agent's aversion of misestimating future rates and $\pi_t^j f$ represents his/her loss function. A given forecast error is all the more costly as the aversion is high. At the equilibrium, equation (2) implies:

$$c_{it}^{j} = -\pi_t^j df / dI_{it}^{j}, \qquad \text{i=1,2,…,n} \tag{3}$$

This equilibrium condition leads to I_{it}^{j*}, the optimal amount of information of type *i* used by agent *j* at time *t*. Equation (3) says that this amount of information is chosen in such a way that the marginal gain - i.e., the marginal decrease in the loss function - due to the decrease in the forecast error equals the unit cost. Note that when the cost/aversion ratio c_{it}^{j} / π_t^j tends to zero ($c_{it}^{j} \to 0$ or $\pi_t^j \to \infty$), then I_{it}^{j*} converges to all available information of type *i*. When information of all types is costless, then the expected quadratic forecast error, which is equivalent to the forecast error variance, cannot be reduced further. In this case the economic rationality converges to the Muthian rationality (Muth, 1960). Conversely, for a

[2] Examples of types of information include actual and past values of the variable to be forecasted and macroeconomic variables.

[3] Our theoretical approach keeps the spirit of Feige and Pearce (1976) model but differs from it on two major points: (i) we relate the information used to the expected quadratic error and not to the ex-post quadratic error, so that f is clearly a behavioral function; (ii) we relax the assumption that informational costs and amounts of information are constant over time and allow these magnitudes to be time-varying.

given π_t^j, the forecaster ignores all information (and becomes a noise-trader) when the cost exceeds the limit value corresponding to his/her maximum marginal gain. Generally speaking, the optimal amount of information may differ from an agent to another because of the discrepancies in the individual cost/aversion ratios c_{it}^j / π_t^j. This generates heterogeneity in expectation behavior[4] and justifies a representation of expectations in terms of a mixed process at the aggregate level. To illustrate this, consider the two following polar situations giving rise to a mixed process: (i) the market is made by different groups of agents, each of them using a simple process (group-heterogeneity effect); (ii) all forecasters use the same mixed process, which is a combination of simple processes (individual mixing effect). A well-known example of a mixed model of type (i) is the chartist and fundamentalist model by Frankel and Froot (1986), who evidenced the model using exchange rate expectations survey data. Heinemann and Ullrich (2006), following Carlson and Valev (2002), introduce a model of type (i) defined as a weighted average of forward looking (fully rational) agents and backward looking (extrapolative, adaptive and regressive) agents. They validate the mixed model using survey data on inflationary expectations. In fact, because some of the groups may also be made by forecasters using mixed processes, the two effects (i) and (ii) may operate simultaneously and this reinforces the relevance of an overall mixed model. Abou and Prat (2000) and Prat and Uctum (2000, 2007) have found similar mixed models using stock market and foreign exchange market survey data, respectively. These authors address the two effects (i) and (ii) without distinguishing them empirically because of the aggregate data used. Oberlechner (2001) found, as a result of his questionnaire and interview survey among experts and traders on four European foreign exchange markets, that most agents use both fundamental and chartist methods whereas others use single methods, the frequency of the different forecasting methods depending on horizons. These last results support the two effects (i) and (ii).

It should be emphasized that the cost/aversion ratio is not an observable magnitude and therefore its relation with expectation formation is not testable. However, the theory proves useful in that the change over time and across forecasters of this ratio can explain why, at the aggregate level, the expectation process can be mixed and the set of information be time-varying. Our goal is precisely to analyze empirically these two issues using survey data on oil price expectations.

3. The survey data

At the beginning of each month, « Consensus Forecasts » (CF) asks 180 or so economy and capital market specialists in approximately 30 countries to estimate future values of a large number of economic variables for 3-month and 12-month horizons. These variables are the production growth rate, inflation rate, unemployment rate, wage rates, new housing starts, company profits, interest rates, foreign exchange rates, West Texas Intermediate (WTI) oil price…. The WTI is a type of crude oil used as a benchmark in oil pricing and the underlying commodity of New York Mercantile Exchange's oil futures contracts. It represents the international reference spot price of the US oil (US$ per barrel), and its global benchmark role is reinforced by the rejection of the regionalisation hypothesis

[4] The heterogeneity in expectational models used by agents has been evidenced by MacDonald and Marsh (1993).

(Gülen, 1999). Towards the end of each month, CF sends each of the bodies (scattered throughout the world) who have agreed to participate in the survey, a questionnaire which asks for their opinion on the future numerical values of WTI oil price. The consensus is the arithmetic average of the individual expected values of oil price and is published in the monthly CF newsletter. These consensus time series are used in this paper over the period November 1989 to December 2008.

Respondents are commercial or investment banks, industrial firms and forecast companies, whose forecasts influence many market participants' decisions. These experts are identified with a confidential code, which only mentions their country. They are only asked to reply when they are sufficiently concerned by an economic variable. Only one third of the 180 experts of CF answer the questions concerning future values of oil price. This confirms that experts who respond are those who are informed about the oil market and who are professionally concerned by the requested horizons. In this way, noise traders cannot bias the consensus because only informed agents are asked to respond. Since the individual answers are confidential (i.e. only the consensus is disclosed to the public with a time lag) and since each individual is negligible within the consensus, it is difficult to say that, for reasons which are inherent to speculative games, individuals might not reveal their « true » opinion. The CF requires a very specific day for the answers, i.e. at the beginning of the following month. As a rule, this day is the same for all respondents.[5] Finally, given that questions concern the expected levels of oil price, the expected change rate can only be determined with respect to the last spot price which is assumed to be known by the individuals the day they answer (reference price). It is thus clear that any mistake in the choice of the reference price date implies a mistake in the measurement of the expected change. However, the price values considered in this paper being dated from the day required by CF for the answers, the concentration of the answers on the same day implies that we can retain the same reference price for all respondents.

Another important issue is the real meaning of the reported forecasts in the survey. Especially, if experts report a risk-adjusted expectation (i.e., their opinion on the future value of the product of the kernel price and the spot price) instead of their actual expectation, that is, if they do not respond what they are asked to, then any attempt to model the consensus according to a pure expectation process would be of course irrelevant. However, there are reasons to interpret the provided response as an expectation, as CF do: the existence of a 3- and 12-month ahead forward WTI oil market[6] yields agents to distinguish their expectation from the forward price, and then to separate the expected oil price from the risk premium.

We assume that the opinion variable of agent j is his expected return $E_t^j(p_{t+\tau} - p_t) = \tilde{p}_{t,\tau}^j - p_t$, where $\tau = 3, 12$. Since agents are asked by CF to give their opinions about the level (and not the log-level) of the future oil price, they express their responses as $\tilde{P}_{t,\tau}^j = P_t \exp(\tilde{p}_{t,\tau}^j - p_t)$, where $\tilde{P}_{t,\tau}^j$ and P_t denote the expected oil price and the actual price, respectively. Therefore, at the aggregate level, the expected oil price should be the geometric average of $\tilde{P}_{t,\tau}^j$. However, the consensus value published by CF is an arithmetic average of individually expected prices. Hence, constructing the aggregate expected return using the latter measure instead of the former generates a systematic bias. It can be shown that the wider the dispersion of individual expectations the larger is the aggregate bias. Because in

[5] We notice that this day is dated at the first Monday of the month until March 1994 and the second Monday of the month since April 1994 with the exception of days off, in which case the nearest following worked day is applicable. The effective horizons however always remain equal to 3 and 12 months. If, for instance, the answers are due on the 3rd of May (which was the case in May 1993), the future values are asked for August 3, 1993 (3 month-ahead expectations) and for January 3, 1994 (12 month-ahead expectations).

[6] In case of absence of arbitrage opportunity, the forward oil price equals the spot price plus the storage costs.

our data this dispersion is rather low at each point in time for the two horizons,[7] this bias will be represented by a constant. We will therefore introduce in each process an intercept to capture this bias, and write the dependent variable as $\tilde{p}_{t,\tau} - p_t$, where $\tilde{p}_{t,\tau}$ is the logarithm of the arithmetic average of $\tilde{P}^j_{t,\tau}$ provided by CF. Figure 1 compares $\tilde{p}_{t,3} - p_t$ and $\tilde{p}_{t,12} - p_t$, both expressed in percent per year: despite a substantial correlation (R^2=0.78), the Figure exhibits specific fluctuations that are to be modeled.

4. Are oil price expectations rational?

The empirical exercise presented hereafter aims to identify the relevant process used by the respondents to Consensus Forecasts. We will first examine the relevance of the REH, which describes a situation in which the consensus is generated by an underlying process based on all available information, this process being unknown to the investigator. We will begin by implementing ADF tests to the three variables of interest: p_t, $\tilde{p}_{t,3}$ and $\tilde{p}_{t,12}$. At a 1% level of significance (with an intercept and one lag), all variables were I(1). Therefore we conducted the unbiasedness tests on the following specification[8] where all variables are found to be I(0) at the 1% level :

$$\tilde{p}_{t,\tau} - p_t = a_\tau \; (p_{t+\tau} - p_t) + b_\tau + \nu_{\tau,t} \tag{4}$$

Since our 3-month and 12-month ahead expectations are observed in a monthly frequency, a possible overlapping data bias may affect the OLS variance-covariance matrix of estimates. In order to adjust the OLS standard errors, we use the Newey-West methodology as suggested by Estrella and Hardouvelis (1991). Alternatively, we circumvent the overlapping data problem by picking out from our 3-month and 12-month expectations data every third and twelveth observations, respectively. Table 1 gives the results for these tests for the two horizons:

Table 1. Unbiasedness Tests

	Overlapping data	Non-overlapping data
3-month horizon (1989:11-2008:09)		
	227 monthly observations	75 quarterly observations
a	0.020 (0.63)	0.060 (1.63)
b	-0.043 (-5.09)	-0.046 (-3.96)
$\overline{R}^2$	-0.002	0.011
SE	0.072	0.069
DW	0.73	0.95
12-month horizon (1989:11-2007:12)		
	218 monthly observations	18 annual observations
a	0.072 (1.36)	0.101 (1.39)
b	-0.064 (-3.99)	-0.055 (-1.51)

[7] For each point in time, the cross-section coefficient of variation (i.e., the ratio of the standard deviation of individual answers and the consensus) lies between 0.07 and 0.20 for the 3-month horizon and between 0.09 and 0.23 for the 12-month horizon. This indicates that the heterogeneity of individual expectations is neither negligible, nor large enough for the consensus to be irrelevant.

[8] To avoid a bias resulting from measurement error on regressor, we choose the expected change in oil price as the endogenous variable.

$\overline{R}^2$	0.023	-0.005
SE	0.120	0.133
DW	0.34	1.24

Notes. Newey-West estimates are those of Equation (4). The numbers in parentheses are the Student t-values.

The hypothesis of unbiasedness involves testing the joint hypothesis that the slope *a* is 1 and the intercept *b* is zero.[9] Nevertheless, because of the possible measurement bias on the expected variable leading to a non-zero intercept, only the value of the slope accounts for the unbiasedness. Our results strongly reject the unbiasedness hypothesis for the consensus both with the overlapping data and non-overlapping data sets (*a* is insignificantly different from zero). Further, to explore the hypothesis of a learning mechanism towards the rationality, we allowed the slope in Equation (4) to be time-varying over the whole sample. We then estimated a state-space model using the Kalman-Filter methodology where $a_{\tau,t}$ is supposed to be an AR(1) with drift. Estimated time-varying standard errors of $a_{\tau,t}$ ($\tau = 3$, 12) showed that at any time the values of the slope do not depart significantly from zero at the 5% level. This implies that no convergence of the consensus towards the REH occurs for either horizon. Moreover, a systematic zero-slope even suggests that there exists no significant group of rational agents within the consensus at any time. We also checked for this hypothesis by estimating a flexible model as suggested by Heinemann and Ullrich (2006), following Carlson and Valev (2002). This model is a weighted average of a rational expectations component, given by the ex-post realization of the variable of interest, and a set of backward-looking extrapolative, regressive and adaptive components. We estimated such a flexible specification for oil price expectations where the backward-looking part of the model is given by equation (8) below, and found that the proportion of the group of rational agents collapses to zero.[10] The insight behind the rejection of the REH is that processing all available information is too costly compared to the corresponding marginal gain, as developed in section 2. The rejection of the REH rises the question of how oil price expectations are formed.

5. A mixed model of expectation formation

We begin by considering the three traditional expection processes of the literature, namely the extrapolative, the adaptive and the regressive processes. If all the agents were extrapolative, the expected change in oil price would depend on the rate of change observed during the n_τ last months: [11]

$$\tilde{p}_{t,\tau} - p_t = \alpha_{1,\tau} + \gamma_\tau \, (p_t - p_{t-n_\tau}) + \varepsilon_{1,t,\tau} \tag{5}$$

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[9] This condition is not sufficient to prove the REH but its failure is sufficient to reject the REH.

[10] We also tested the hypothsesis that one of the backward processes composing the equation (8) might represent the rational agents' expectations by regressing each process on the ex-post change in oil price. The hypothesis was drastically rejected for each process and for each horizon.

[11] The general expression of the extrapolative process is $\tilde{p}_{t,\tau} - p_t = \alpha_{1,\tau} + \sum_{i=1}^{n_\tau} \gamma_{\tau,i} (p_{t-i+1} - p_{t-i}) + \varepsilon_{1,t,\tau}$.

Our final results led to the conclusion that the extrapolative coefficients $\gamma_{\tau,i}$ are insignificantly different one from the others. For sake of simplicity, we use the reduced version of this process, which is given by equation (5).

where $\varepsilon_{1,t,\tau}$ is a stochastic error term. Although the theoretical sign of the parameter γ_τ of the extrapolative process is more likely to be positive, a negative value is conceivable in the extent that it can reflect a naive regressive process (systematic turning tendency).

We consider now the case where all the agents are adaptive. Our adaptive process says that the expected change in oil price is based on an "early revision" mechanism of forecast errors that we formulate as follows:

$$\tilde{p}_{t,\tau} - p_t = \alpha_{2,\tau} + (1-\beta_\tau)(\tilde{p}_{t-1,\tau} - p_t) + \varepsilon_{2,t,\tau} \tag{6}$$

where $0 \le \beta_\tau \le 1$. In a standard adaptive model, the time horizon corresponds to the frequency of observations, which is not the case with our data. But it is possible – indeed very likely – that experts will not wait until the three month horizon is completed to revise their expectations. When, during the survey procedure, the price at the beginning of the month is known, the individuals will probably compare this price to the one which they had expected during the last survey, i.e., a month before, and not three months before as the standard adaptive model assumes.[12] This assumption is supported by the fact that the early revision model defines $\tilde{p}_{t,3}$ as a weighted average of past monthly values of p_t, while the standard adaptive model defines $\tilde{p}_{t,3}$ as a weighted average of past quarterly values of p_t. Hence, with our monthly data, equation (6) seems more appropriate than the standard model.

In the case all the agents make regressive forecasts, the expected change in oil price is supposed to be represented by a standard error correction model (ECM):

$$\tilde{p}_{t,\tau} - p_t = \alpha_{3,\tau} + \mu_{1,\tau}(\bar{p}_{t-1} - \tilde{p}_{t-1,\tau}) + \mu_{2,\tau}(\bar{p}_t - \bar{p}_{t-1}) + (\tilde{p}_{t-1,\tau} - p_t) + \varepsilon_{3,t,\tau} \tag{7}$$

where $0 \le \mu_{i,\tau} \le 1$ $(i = 1,2)$.[13] The target price $\bar{p}_t$ is supposed to depend on macroeconomic fundamentals, which we will specify later. It represents some long-run value of the oil price and thus it is supposed to be the same for the two horizons of expectations. According to (7), the expectation $\tilde{p}_{t,\tau}$ converges towards its target value $\bar{p}_t$ (when $\alpha_{3,\tau} = 0$), while in the adaptive model (6), $\tilde{p}_{t,3}$ converges towards the observed price p_t (when $\alpha_{2,\tau} = 0$). Therefore, the adaptive process is not, here, a particular case of the error-correction model as it is the case with the standard adaptive and ECM schemes when the slopes of the components of the the latter are equal.

We turn now to the more general situation where the consensus is characterized by the group-heterogeneity effect and/or the individual weighting effect described above. The heterogeneity found by MacDonald and Marsh (1993) concerning the choice of the expectational model implies that on the aggregate level a mixed expectational model should be envisaged. The mixed model we consider is then obtained as a linear combination of the three basic processes:

[12] The standard adaptive process is $\tilde{p}_{t,\tau} - \tilde{p}_{t-\tau,\tau} = \beta'_\tau (p_t - \tilde{p}_{t-\tau,\tau})$. The assumption of an early revision of expectations leads to the relation $\tilde{p}_{t,\tau} - \tilde{p}_{t-1,\tau} = \beta_\tau(p_t - \tilde{p}_{t-1,\tau})$, which is formally equivalent to (6) with $\alpha_{2,\tau} = 0$ and $\varepsilon_{2,t,\tau} = 0$.

[13] The standard ECM is $\tilde{p}_{t,\tau} - \tilde{p}_{t-1,\tau} = \mu_{1,\tau}(\bar{p}_{t-1} - \tilde{p}_{t-1,\tau}) + \mu_{2,\tau}(\bar{p}_t - \bar{p}_{t-1})$. Rearranging terms so as to get the expected change in oil price at the left hand side yields equation (7).

$$\tilde{p}_{t,\tau} - p_t = k_{0,\tau} + k_{1,\tau}(p_t - p_{t-n_\tau}) + k_{2,\tau}(\tilde{p}_{t-1,\tau} - p_t) + k_{3,\tau}(\bar{p}_{t-1} - \tilde{p}_{t-1,\tau}) + k_{4,\tau}(\bar{p}_t - \bar{p}_{t-1}) + \varepsilon_{t,\tau} \quad (8)$$

where the second term in the right-hand side of (8) represents the extrapolative component of expectations, the third term the adaptive component and the fourth and fifth terms the error-correction form regressive components. We will show in the next section that macroeconomic fundamentals affect the expected change in oil price throughout the target price $\bar{p}_t$. Denoting $d_{1,\tau}$, $d_{2,\tau}$ and $d_{3,\tau} = 1 - d_{1,\tau} - d_{2,\tau}$ $(0 \le d_{i,\tau} \le 1, i = 1,2,3)$ the weighting coefficients for the extrapolative, adaptive and regressive components respectively, the composite coefficients in (8) can be written in terms of these weighting coefficients and the structural parameters of the basic processes as $k_{0,\tau} = d_{1,\tau}\alpha_{1,\tau} + d_{2,\tau}\alpha_{2,\tau} + d_{3,\tau}\alpha_{3,\tau}$, $k_{1,\tau} = d_{1,\tau}\gamma_\tau$, $k_{2,\tau} = d_{3,\tau} + d_{2,\tau}(1-\beta_\tau)$, $k_{3,\tau} = d_{3,\tau}\mu_{1,\tau}$, $k_{4,\tau} = d_{3,\tau}\mu_{2,\tau}$. A given weighting coefficient will prove significant if the forecasters have employed the corresponding process alone or by combining it with some others a significant number of times in the sample period. In the first case, the model stems from the aggregation of heterogenous groups of agents using simple forecasting schemes (group-heterogeneity effect) and in the second case it results from individual mixed forecasting behavior (individual mixing effect). As a result, equation (8) can reduce to a combination of two of the three basic processes (5) to (7), to one of these basic processes or, as a limit case, to a naive process $\tilde{p}_{t,\tau} - p_t = \varepsilon_{t,\tau}$. In particular, the case $d_{2,\tau} = 0$ corresponds to the extrapolative-regressive process traditionally attributed to the chartist-fundamentalist agents, which keeps the same specification as in (8) but introduces a restriction in the composite parameters.

6. Empirical determination of the oil price target

We first posit that $\bar{p}_t$ is the trend component of the expected price, this being all the more relevant with a long time-horizon.[14] We can thus decompose tautologically the 12-month price expectation as a long term component given by the target price and a short term component given by the spread to the target:

$$\tilde{p}_{t,12} = \bar{p}_t + (\tilde{p}_{t,12} - \bar{p}_t) \quad (9)$$

To identify the factors of $\bar{p}_t$ we must account for the fact that the WTI crude oil can be viewed as an investment asset[15] and a physical factor of production. This implies that the target price is determined independently by a theoretical fundamental financial value, which agents at first sight refer to as a benchmark, and some macroeconomic effects:

$$\bar{p}_t = f_t + \theta' x_t \quad (10)$$

where f_t is the logarithm of the fundamental value while x_t and θ are vectors of macroeconomic variables and coefficients.

Reporting (10) into (9) yields :

[14] Note that, in a behavioral equilibrium exchange rate modeling framework, Clark and MacDonald (1999) suppose that the expectation and the target are driven by the same long-run economic fundamentals.

[15] This aspect is evidenced by the behavior of the speculative investment funds which make arbitrages between different markets in order to maximize the return or to minimize the risk.

$$\tilde{p}_{t,12} - f_t = \theta' x_t + u_t \qquad (11)$$

with $u_t = \tilde{p}_{t,12} - \bar{p}_t$.

In Equation (11) the left-hand side variable is not observable since f_t is unknown to the investigator although it is known to the agents. We suppose that the change in f_t is determined by the riskless interest rate i_t and a constant risk premium ϕ.[16] We estimate f_t so as to minimize the sum of squared values of the dependent variable of (11) :

$$\underset{f_o,\phi}{Min} \sum_t (\tilde{p}_{t,12} - f_t)^2 \qquad (12a)$$

$$f_t = f_{t-1} + i_{t-1} + \phi \qquad (12b)$$

where f_0 is the starting value of f_t and i_t stands for the 3-month US Treasury Bill Rate.[17] A grid search over the sample period led to the optimal values $\hat{f}_0 = 2.55$ and $\hat{\phi} = 3.0$ when expressed in percent per year. [18] Figure 2 shows that the fundamental value $\hat{f}_t$ calculated as (12) represents the upward sloped trend of the price $\tilde{p}_{t,12}$. A backward simulation has revealed that these results are consistent with the 15 US$ averaging price values observed in the 1960s. Moreover, the value of the risk premium is acceptable compared to the premia estimated on other asset markets.

The dependent variable being now observable, we can identify the macroeconomic factors x_t in Equation (11). Among a large number of variables tested,[19] the four variables we retained are the Hodrick–Prescott smoothed values of the relative spread between world consumption and production of crude oil (which is an excess demand indicator), the expected values of the CPI-based rate of inflation for the current year, the expected values of the CPI-based rate of inflation for the following year and the expected values of the growth rate in real GDP for the following year. We assume that the impact of the prices of competitive energies is captured by the excess demand indicator through the world consumption of crude oil. All these dependent and independent variables are found to be I(1) following the ADF unit root test and their levels are considered in the target regression. The Newey-West estimates of Equation (11) over the sample period led to significant coefficients with the expected positive signs (Table 2, model (M0)).[20] Nevertheless, diagnostic tests in Table 3 show that the residuals of the model M0 are autocorrelated regarding the DW test statistics and

[16] This method of determination of f_t is similar to the one used to assess the fundamental value of equities where dividends appear as an additional variable.

[17] As a first attempt we introduced a weighted average of the 3-month Treasury Bill Rate and the 10-Year Treasury Bond Yield. As expected, the minimum of the sum of squares has led to the selection of the short term rate.

[18] A time varyig risk premium has also been considered by assuming that the premium depends on the variance of the rate of change in oil price, but the coefficient of this variance was found to be zero, leaving in the specification only a positive constant term.

[19] These are the observed and expected values of the change in real GDP, of the real investment, of short and long term interest rates, of the rate of unemployment, all relative to USA, plus a world excess demand indicator (CNUCED).

[20] There is no collinearity problem affecting the variances of the estimates since no R^2 between the exogenous variables exceeds 0.5.

heteroskedastic regarding the Pagan-Breusch-Godfrey (PBG) test statistics. Moreover the residual-based ADF unit root test clearly indicates that this model does not define a cointegration relation even at the 10% level. These test results may be due to structural changes impulsed by exogenous shocks that are known to have occurred over the period analyzed, such as the Gulf crisis, the change in OPEC's behavior, or the evolution of the oil production marginal cost. To account for these potential parameter instability factors, we estimated Equation (11) by implementing the Bai and Perron (1998) methodology (BP hereafter) with multiple endogenous breaks. This methodology is outlined in the Appendix.

Table 2. Determination of the target: estimates of the model with no break and with 3 breaks

Independent variables	**Model with no break**	**Model with 3 breaks**	
	(M0)	**(M3)**	**(M3')**
c_1	-3.34 (-20.32)	0.61 (1.36)	-0.36 (-5.83)
c_2		-0.75 (-2.04)	-1.26 (-16.19)
c_3		-2.09 (-4.92)	-2.09 (-4.97)
c_4		-2.82 (-10.61)	-2.82 (-10.71)
xdi_1	14.80 (16.64)	-4.71 (-1.73)	
xdi_2		-6.23 (-1.60)	
xdi_3		7.78 (3.15)	7.78 (3.18)
xdi_4		14.25 (11.01)	14.25 (11.12)
$eicy_1$	0.18 (8.89)	0.01 (0.42)	0.05 (2.28)
$eicy_2$		0.21 (4.53)	0.26 (16.42)
$eicy_3$		0.12 (4.41)	0.12 (5.46)
$eicy_4$		0.15 (4.08)	0.15 (4.12)
$eify_1$	0.31 (10.38)	0.08 (2.20)	0.13 (4.02)
$eify_2$		0.11 (1.58)	
$eify_3$		0.10 (1.94)	0.10 (1.96)
$eify_4$		0.12 (3.14)	0.12 (3.17)
$egfy_1$	0.028 (1.90)	-0.05 (-1.32)	
$egfy_2$		0.19 (5.89)	0.17 (4.59)
$egfy_3$		0.07 (3.29)	0.07 (3.32)
$egfy_4$		0.11 (4.21)	0.11 (4.25)

Notes. Regression equation is $\tilde{p}_{t,12} - f_t = \sum_{j=1}^{m+1} \theta_j{}' \, x_t 1_{t \in I_j} + v_t$ (equation (A1) in the Appendix).

The full sample period is 1989.11-2008.12. The dependent variable is $\tilde{p}_{t,12} - f_t$ (see equation (11)). The independent variables are defined as *xdi* =excess demand indicator, *eicy*= expected inflation for the current year, *eify* = expected inflation for the following year, *egfy*= expected growth rate for the following year. Model (M3') is the model (M3) re-estimated without the insignificant regressors. Subscripts correspond to sub-periods (to full sample in the case of no break). Figures in parentheses are t-statistics based on Newey-West heteroscedasticity and autocorrelation consistent covariances.

We found three break dates which are 1993:06, 1998:11 and 2004:09, dividing the full sample period 1989:11-2008:12 into four sub-samples (Table 3). Although one cannot associate meaningful structural events to these breakpoints, the sub-periods seem to reflect the historical tension streams known to have characterized the oil market, as we will comment more in-depth below. The 95% confidence intervals associated with these estimated dates are tight enough to conclude that these estimates are significant. We then reestimated the breakdates over refined sub-samples (refinement) in order to check for their robustness. The refinement estimates led to identify the same breakpoints with the same confidence intervals. Interestingly, our endogenous sample separation corresponds approximately to the one suggested exogenously by Ye, Zyren and Blumberg (2009). In Table 3 are also reported the $\overline{R}^2$, the SSR, the BIC and LWZ information criteria associated with each number of breaks. The sharp decrease in the SSR and the information criteria shows a substantial improvement in the goodness of the fit as the number of breakpoints increases. We consider that the number of breakpoints is three given that at this number the rates of decrease of the SSR and information criteria nearly flat and that the identified sub-periods are not large enough to allow additional breakpoint search.

Table 3. Determination of the target: break dates, goodness of fit indicators, information criteria and diagnostic tests

	Model with no break (M0)	**Model with 1 break (M1)**	**Model with 2 breaks (M2)**	**Model with 3 breaks (M3)**	**(M3')**	**Model with 3 breaks: diagnostic tests over sub-periods (M3')**			
Period	1989:11-2008.12					89:11-93:06	93:07-98:11	98:12-04:09	04:10-08:12
Break-points		$t_1^* = 2004.09$ [04.08, 04.10]	$t_2^* = 1998.11$ [98.06, 99.04] $t_1 = 2004.09$	$t_3^* = 1993.06$ [93.02, 93.10] $t_2 = 1998.11$ $t_1 = 2004.09$					
Nb Obs	230	230	230	230	230	44	65	70	51
$\overline{R}^2$	0.796	0.918	0.947	0.966	0.968	0.870	0.898	0.631	0.881
SSR	5.104	1.999	1.263	0.789	0.815	0.064	0.050	0.353	0.245
BIC	-3.689	-4.486	-4.803	-5.131	-5.099				
LWZ	-3.558	-4.196	-4.354	-4.522	-4.490				
DW	0.186					0.869	0.531	0.409	0.483
BPG	0.02					0.68	0.06	0.17	0.21
ADF	-3.31					-3.70	-3.78	-4.31	-4.16
1%	*-5.06*					*-4.63*	*-4.52*	*-5.28*	*-5.06*
5%	*-4.48*					*-4.94*	*-3.87*	*-4.62*	*-4.48*
10%									

-4.18		*-3.59*	*-3.55*	*-4.29*	*-4.18*

Notes. BIC and LWZ are Yao's (1988) and Liu, Wu and Zidek's (1997) information criteria depending on the number of breaks. DW, BPG and ADF are Durbin-Watson first order autocorrelation test statistics, Pagan-Breusch-Godfrey heteroskedasticity test F p-values and Augmented Dickey-Fuller unit root test statistics, respectively. In the last three rows, the numbers in italics are MacKinnon's (2000) residual-based asymptotic critical values for the ADF test statistics. t_i^* = endogenously determined *i*'th breakdate within the estimation of model (Mi). (M3') is the model (M3) re-estimated without the insignificant variables. Figures in brackets below estimated break dates are 95% confidence intervals.

Table 2 exhibits the change in the effect of each regressor over the four sub-periods, these being indicated by the subscripts associated to the independent variables. Column (M3') presents the results of the re-estimation of the model with 3 breaks (M3) where the insignificant variables have been removed. Regarding estimates in column (M3'), the excess demand has not affected the 12-month oil price expectations over the two first sub-periods. According to the economically rational expectations theory (section 2) this variable may have been dropped at these sub-periods from the set of relevant information because it does not allow to reduce the forecast error. Note that the excess demand indicator is always positive and has an upward tendency over the period. During the 1990s the oil market is in a regime of surplus production capacity, leading the OPEC to impose production quotas. The excess demand has thus been intentionally kept positive by the OPEC during the two first sub-periods. Between the end of the 1990s and 2004, the excess desired supply of crude oil has been substantially reduced until it has vanished on 2004 (see Kaufmann et al, 2004). One reason of this is possibly the fact that the marginal cost of production of the crude oil has rosen discontinuously during the whole period, shifting from about 20 \$/barrel at the beginning of the period to reach 80 \$/barrel towards the end of the period (Lescaroux, 2008). The real supply scarcity characterizing the last two sub-periods led the forecasters to introduce the excess demand factor among their information set. The expected inflation for the current year and the year after have both a positive and significant influence on the expected oil price at each sub-period, except at the second sub-period where only the current year inflation expectations are taken into account. The expected rate of change in GDP for the year after is positively significant for all sub-periods except for the first one. This exception seems in conformity with the surplus production capacity of crude oil observed during the same sub-period. Note that the Gulf crisis (August 1990 - April 1991) which is located in the first sub-period and the 1997 Asian crisis in the second sub-period have not produced abnormal gaps between oil price expectations and their fundamentals (Figure 3): oil price expectations and good price expectations seem to have been affected simultaneously by the crises. The excess oil production capacity that characterized the first two sub-periods is possibly the reason why the two crises have not affected severely and persistently oil price expectations. Overall, the influential regressors of the target are among the ones found by the literature on oil price forecast models (see introduction).

The BP methodology allowed us to estimate the parameter vector θ for each sub-period. Using (10) we can now calculate the target $\overline{p}_t$. Figure 3 shows that the target price evolves as the 12-month expected price. Regarding the ADF test conducted over each sub-period, we found that the residual $\hat{u}_t$ in (11) is stationary between the breakpoints at the 10% level of significance (Table 3, right panel). Note that this level possibly could have been lowered if a wider set of data was available allowing a more accurate sampling of the full period. We can reasonably conclude that $\overline{p}_t$ is an acceptable target for $\tilde{p}_{t,12}$ over each subperiod, and thus over the full period. The PBG heteroskedasticity test failed to reject the null of no heteroskedasticity at the 5% level, confirming the stationarity hypothesis of $\hat{u}_t$ in each of the four sub-periods. However, the low values of the DW statistic indicate that u_t is autocorrelated within the subsamples with roughly unchanging autoregressive coefficients. This stable autocorrelation suggests to model linearly $\tilde{p}_{t,12}$ by adding short term components to the long term component $\bar{p}_t$. The expectation process (8) is based on this idea.

Given the values of $\hat{f}_t$, the inference for θ in column (M3') in Table 2 yields to an estimated value of $\bar{p}_t$ following (10), that is:

$$\hat{\bar{p}}_t = \hat{f}_t + \hat{\theta}' x_t \tag{13}$$

7. Estimation of the mixed expectation process

Reporting the target value (13) into the expectation process (8) allows estimating the latter for the 3-month and 12-month horizons.[21] ADF tests show that all the variables entering (8) irrespective the horizon are I(0). The fact that agents form their forecasts for both horizons simultaneously and that the horizons are nested leads to a substantial correlation between the expected change in oil price for $\tau = 3$ and 12 (see Figure 1). On the other hand, the equation (8) includes common regressors for the two horizons. These issues imply a correlation between the contemporaneous residuals across the two equations that we must account for. We then estimate the two equations as a system by using the seemingly unrelated regression (SUR) methodology which is appropriate when all the right-hand side regressors are assumed to be exogenous and the errors are contemporaneously correlated[22] and heteroskedastic. Besides, our 3-month and 12-month ahead expectations are observed in a monthly frequency, and this overlapping feature of the data leads to inconsistent variances of estimates since it generates moving average in the errors. The Newey-West method is relevant in this context because it provides variances that are consistent to the serial correlation, but it is a single-equation approach. If the estimated values of a given parameter from the two methods turn out to be significantly close one to each other, we can consider that the two statistical problems mentioned above are taken into account. Table 4 presents the results from SUR, Newey-West and, for comparison, OLS methods.

Table 4 : Estimation of the mixed expectation model.

	SUR	Newey-West/OLS
3-month horizon		
n	2	2

[21] Reporting the target (10) into the process (8), a one-step estimation procedure was also conceivable so that the parameters θ and k would have been estimated simultaneously. This approach would consist in estimating a two-horizon system of reduced models with non-linearities in its parameters and allowing in the meantime for these parameters to be affected by structural breaks. Such a model would clearly be untractable to estimate since it would require nesting the BP and the non-linear least squares methods.

[22] The correlation between $\hat{\varepsilon}_{t,3}$ and $\hat{\varepsilon}_{t,12}$ is found to be 0.66.

k_0	-0.007	-0.006
	(-3.46)	(-2.82) (-3.06)
k_1	0.19	0.23
	(9.72)	(8.86) (9.94)
k_2	0.79	0.79
	(32.28)	(32.34) (28.80)
k_3	0.05	0.08
	(2.81)	(3.70) (4.57)
k_4	0.23	0.21
	(5.98)	(4.08) (5.33)
$\overline{R}^2$	0.871	0.878
SE	0.027	0.026
BG(1)	0.124	0.098
BG(4)	0.192	0.109
BPG	0.041	0.039
12-month horizon		
N	3	3
k_0	-0.005	-0.004
	(-2.70)	(-1.87) (-2.01)
k_1	0.06	0.09
	(4.78)	(4.28) (6.28)
k_2	0.88	0.90
	(58.83)	(61.11) (56.37)
k_3	0.11	0.09
	(3.90)	(2.31) (3.15)
k_4	0.24	0.21
	(6.16)	(3.19) (5.37)
$\overline{R}^2$	0.96	0.961
SE	0.025	0.025
BG(1)	0.0001	0.0005
BG(4)	0.001	0.0002
BPG	0.253	0.067

Notes. The estimated equation is (8), where the target variable is given by (13). The estimation covers the period 1989:11-2008:12. BG and BPG are Breusch-Godfrey serial correlation LM test F p-values for the indicated lag and Pagan-Breusch-Godfrey heteroskedasticity test F p-values, respectively. Figures in parentheses are t-statistics, based on Newey-West and OLS methods respectively in column 3.

Whatever the methodology implemented, the inference provides a good fit for each horizon, as shown by Figures 4 and 5 where the SUR fits are represented.[23] The estimates are found to be significantly positive as expected and stable regarding the Quandt-Andrews test (the F p-values associated to the null of stability are 0.99 and 0.79 for the 3-month and the 12-

[23] It should be noticed that equation (8) involves at both sides the log of the spot price at time t. This raises the question of whether or not there exists some necessity to find good fits. To check for this issue, we derived from (8) an equivalent equation in which the actual price in the left hand side has been moved to the right hand side, leaving at the left hand side the expected price in log-level. There is thus no possibility for this last equation to be necessarily validated because of common information on both sides of the equation. The estimated coefficient of the price at the right hand side appeared to be very significantly equal to 1 for each horizon, all the other parameters being significantly unchanged with respect to those of regression (8). This confirms that the expected rate of change in oil price is the relevant variable to be modeled. Concerning the target price, since it does not depend on observed and expected oil price, it precludes the possibility of a necessary correlation in (8).

month horizons, respectively). Preliminary results have shown that when a target estimated with no breakpoint (that is, the model M0 in Tables 2 and 3) was introduced in the expectation model (8), the regressive components were not significant and the residuals did not have desirable properties. The estimates in Table 4 are not significantly different according to whether the system approach or one of the single equation approaches has been applied. This implies that the contemporaneous correlation of residuals from the two horizons does not affect the inference when single equation approaches are used. Moreover, the convergence of the results from the Newey-West and OLS methods imply that our overlapping data do not alter seriously the accuracy of the estimators.[24] Regarding the Breusch-Godfrey (BG) serial correlation LM test, the null of no-autocorrelation of the residuals is rejected for the 12-month horizon but is not rejected for the 3-month horizon. Again, comparison with the Newey-West results shows that the autocorrelation in the case of the 12-month model[25] does not weaken the significance of the parameters. According to PBG test results the null of no heteroskedasticity is not rejected at the 5% level for the 12-month horizon and at the 1% level for the 3-month horizon.

The optimal length found by a grid search for the extrapolative component is $n_3 = 2$ for the 3-month horizon and $n_{12} = 3$ for the 12-month horizon. Note that this component acts with a positive sign, contrary to what is generally obtained when this process is estimated alone. This result is satisfactory since it conforms to the intuitive idea that the extrapolation should maintain the past direction of the market, especially when a regressive component is also introduced.

For illustrative purposes, we assume that Equation (8) represents a combination of extrapolative, regressive and adaptive processes and we set $d_{1,\tau}$, $d_{2,\tau}$ and thus $d_{3,\tau}$ to 1/3 for both horizons. The estimated values for $k_{i,\tau}, i = 0,...,4$, lead then to the following values of the structural parameters of the basic processes imbedded in Equation (8): $\gamma_3 = 0.58$, $\beta_3 = 0.39$, $\mu_{1,3} = 0.15$, $\mu_{2,3} = 0.70$ and $\gamma_{12} = 0.18$, $\beta_{12} = 0.67$, $\mu_{1,12} = 0.33$, $\mu_{2,12} = 0.73$. According to these simulations, we note that all the structural parameters lie in the theoretical intervals. All the parameters depend highly on the horizon except the one of the change in the target, and this partially explains the discrepencies between the 3- and 12-month expected oil price dynamics (Figure 1). Assume now that equation (8) represents an extrapolative-regressive process ($d_{2,\tau} = 0$). In this case no simulation is needed and all the weights and structural parameters are estimated. According to the horizons, the weights associated to the chartist forecasters are then $d_{1,3} = 0.21$ and $d_{1,12} = 0.12$ and those associated to the fundamentalist are $d_{3,3} = 0.79$ and $d_{3,12} = 0.88$. These estimates are consistent with the findings of the literature that the fundamentalist (chartist) behavior is all the more important as the horizon is long (short). The structural parameters are found to be $\gamma_3 = 0.90$, $\mu_{1,3} = 0.06$, $\mu_{2,3} = 0.29$ and $\gamma_{12} = 0.50$, $\mu_{1,12} = 0.13$, $\mu_{2,12} = 0.27$, which still are theoretically consistent.

8. Concluding remarks

[24] Hitherto, we ignored the feedback effect that is the influence of price expectations on actual prices, which may lead to endogeneity bias. To check for this bias, we calculated the correlations between the residuals and each exogenous variable in the case of each horizon. We found that these correlations are systematically insignificant at the 1% level, suggesting that there is no significant endogeneity bias.

[25] We assessed that this is a first order autocorrelation with a slight magnitude of 0.25.

Using Consensus Forecasts survey data for three and twelve month ahead oil price expectations, we found that the rational expectation hypothesis is rejected, whether it is supposed to hold for all experts or only for a group of them. The insight of the rejection of the rational expectation hypothesis is that processing all available information is too costly compared to the corresponding marginal gain, as suggested by the economically rational expectation theory. A central implication of this framework is that expectations may be based on limited information and may therefore generate systematic forecast errors. The question is then to explore how oil price expectations are formed. Consistently with the economically rational expectations framework, the change over time and across forecasters of the cost/aversion ratio can explain both the change in the expectation process from one period to another and the mixed pattern of the process at the aggregate level. We then suggest a mixed expectation model defined as a linear combination of the traditional extrapolative, adaptive and regressive processes, which can be interpreted as resulting from individual mixing effects and/or group heterogeneity effects. An important issue at this stage was to specify the target value of the oil price intervening in the regressive component. We show that the target price depends on macroeconomic fundamentals whose effects are subject to structural changes, which seem to be consistent with the historical behavior of the OPEC. The system-estimation of the two-horizon expectation model led to validate the three components of the mixed model, which is found to be unaffected by structural changes conditionally on the unstable target price equation. Generally speaking, the fact that the mixing behavior fits the expectational data explains both why the traditional simple processes are inappropriate to describing expectations and why expectations are not rational.

The scope of this study was limited to the analysis of the consensus of oil price expectations. A further study would consist in using disaggregated survey data in order to measure the relative importance of the individual mixing effect and of the group heterogeneity effect, which are implicit in our model. Another promising area would be to analyze the interactions between the observed and expected prices in the oil market.

APPENDIX

Estimation of the target model with endogenous structural breaks

The method suggested by Bai and Perron (1998) consists in rewriting equation (11) by introducing in it m unknown breakpoints (m=0, 1, 2…):

$$\tilde{p}_{t,12} - f_t = \sum_{j=1}^{m+1} \theta_j' x_t 1_{t\in I_j} + v_t \tag{A1}$$

where I_j is the sub-period between break dates t_{j-1} and t_j and $1_{t\in I_j}$ an indicator function such that $1_{t\in I_j}$ = 1 for $t_{j-1} < t \le t_j$ and 0 elsewhere ($t_0 = 1$ and $t_{m+1} = T$). In (A1) all parameters are supposed to be affected by the breaks but some of them may be assumed to be stable (partial-shift model). The approach consists in, first, estimating (A1) for *m*=1 over the entire period and identifying the first breakpoint $\hat{t}_1 = \arg\min_{t\in[1,T]} S_T(t)$, where $S_T(t)$ is the sum of squared residuals from the one-break model with the candidate break date t. The sample is then split into two and a one-break model is estimated over each sub-sample [1, $\hat{t}_1$] and [$\hat{t}_1$,T], yielding two potential break dates, $\hat{d}_1$ and $\hat{d}_2$, respectively. The second estimate $\hat{t}_2$ = $\hat{d}_1$ if $S_T(\hat{t}_1, \hat{d}_1) < S_T(\hat{t}_1, \hat{d}_2)$ and $\hat{t}_2$ = $\hat{d}_2$ otherwise, where $S_T(\hat{t}_1, \hat{d}_i)$, *i*=1,2, is the SSR from model (A1) for *m*=2 breakpoints $\hat{t}_1$ and $\hat{d}_i$. The sample is then partitioned into three and a one-break model is estimated over each sub-sample [1,$\hat{t}_1$], [$\hat{t}_1$+1,$\hat{t}_2$] and [$\hat{t}_2$+1,T], and so forth.

To find the number of breaks, we adopt the strategy suggested by Perron (1997), consisting in estimating additional breakdates until the BIC and LWZ information criteria are minimized. These criteria, introduced by Yao (1988) and Liu, Wu and Zidek (1995) respectively, include a penalty factor compensating the necessary decrease in the SSR with each additional new break. For m breakdates, they are given by $BIC(m) = \ln[S_T(\hat{t}_1,...,\hat{t}_m)/T] + (p^*/T)\ln T$ and $LWZ(m) = \ln[S_T(\hat{t}_1,...,\hat{t}_m)/(T - p^*)] + c_0(p^*/T)(\ln T)^{c_1}$, where $c_0 = 0.299$, $c_1 = 2.1$ and the penalty factor $p^* = (m+1)q + m + p$. Note that an alternative test-based approach is the *sup F* type test as proposed by BP, which allows to test the null of m breaks against the alternative of m+1 breaks. A new breakpoint is then estimated if the null is rejected, and the number of breakpoints is obtained at the first value of m for which the null is not rejected. However, this test procedure requires stationarity of the regressors and therefore is not appropriate with our trended series.

Following Bai (1997b), a 95% confidence interval for the estimated break date $\hat{t}_j$ in the case of trending regressors and stationary residuals can be computed as [$\hat{t}_j - [c/\hat{L}_j] - 1, \hat{t}_j + [c/\hat{L}_j] + 1$], where *c*=11 is the 97.5th quantile of the symmetric limiting distribution derived by the author, $\hat{L}_j = \hat{\delta}' x_{\hat{t}_j}' x_{\hat{t}_j} \hat{\delta} / \hat{\sigma}_v^2$ is a scale factor where $\hat{\delta} = \hat{\theta}_{j+1} - \hat{\theta}_j$ is the magnitude of the shift in parameters due to the breakpoint $\hat{t}_j$ and $\hat{\sigma}_v^2$ the estimated variance of $\hat{v}_t$, and $[c/\hat{L}_j]$ is the integer part of $c/\hat{L}_j$.

Bai (1997a, 1997b) shows that once all m breakpoints are estimated, a reestimation (or refinement) of the first m-1 break dates over refined sample periods is needed. For example, if the first breakpoint estimated over [1,T] is $\hat{t}_1$ and the second one, $\hat{t}_2$, is located in the sub-period [$\hat{t}_1$+1,T], then $\hat{t}_1$ should be reestimated over the period [1,$\hat{t}_2$].

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Figure 1 : 3- and 12-month expected change in oil price

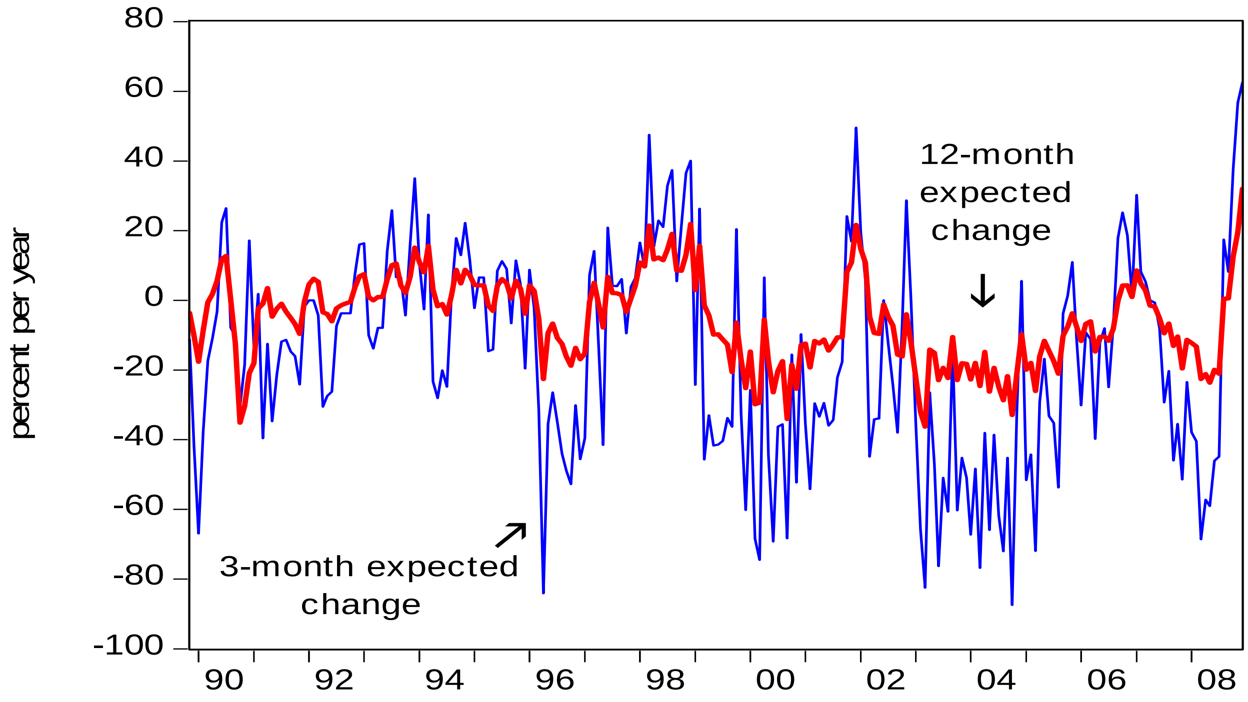

Figure 2 : 12-month oil price expectations and their financial fundamental value

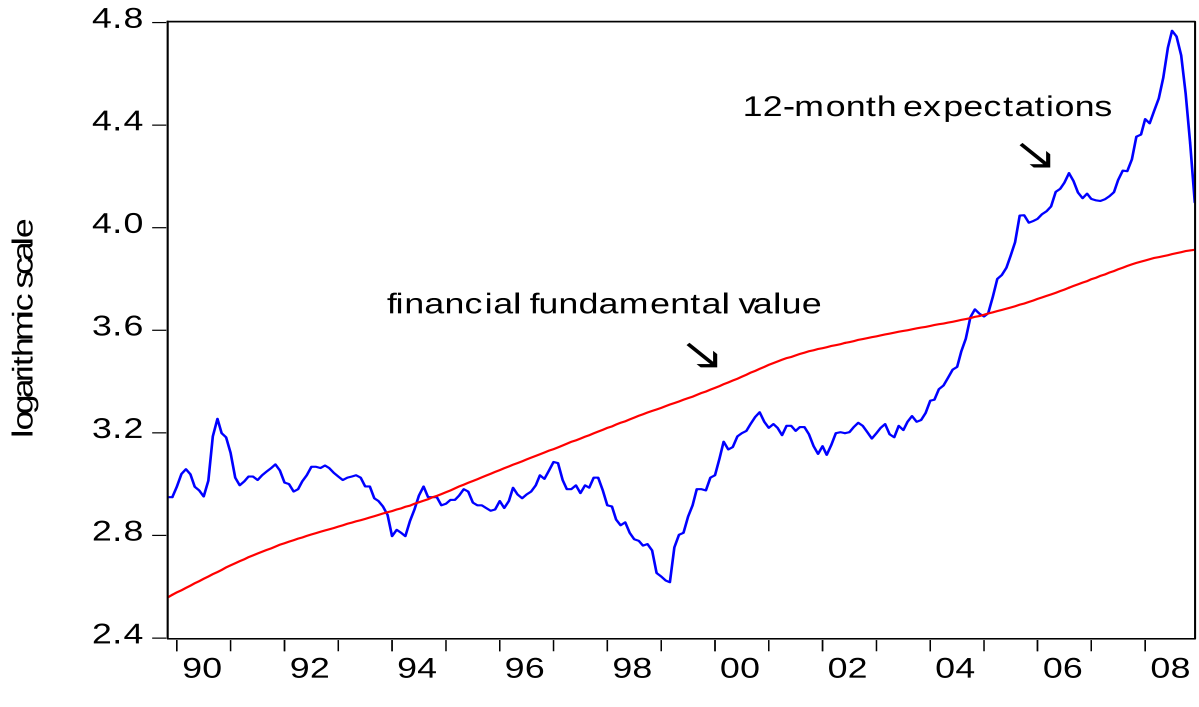

Figure 3 : 12-month oil price expectations and the target value estimated with multiple structural changes

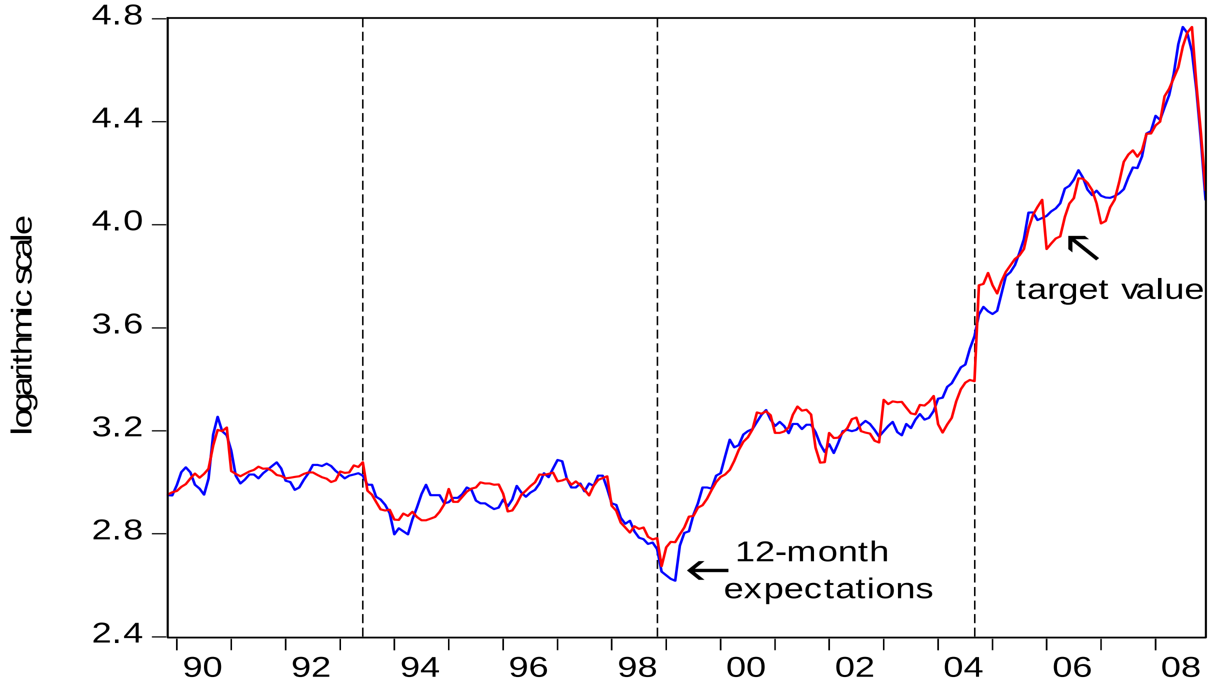

Figure 4 : observed and fitted values of the 3-month ahead expected change in oil price

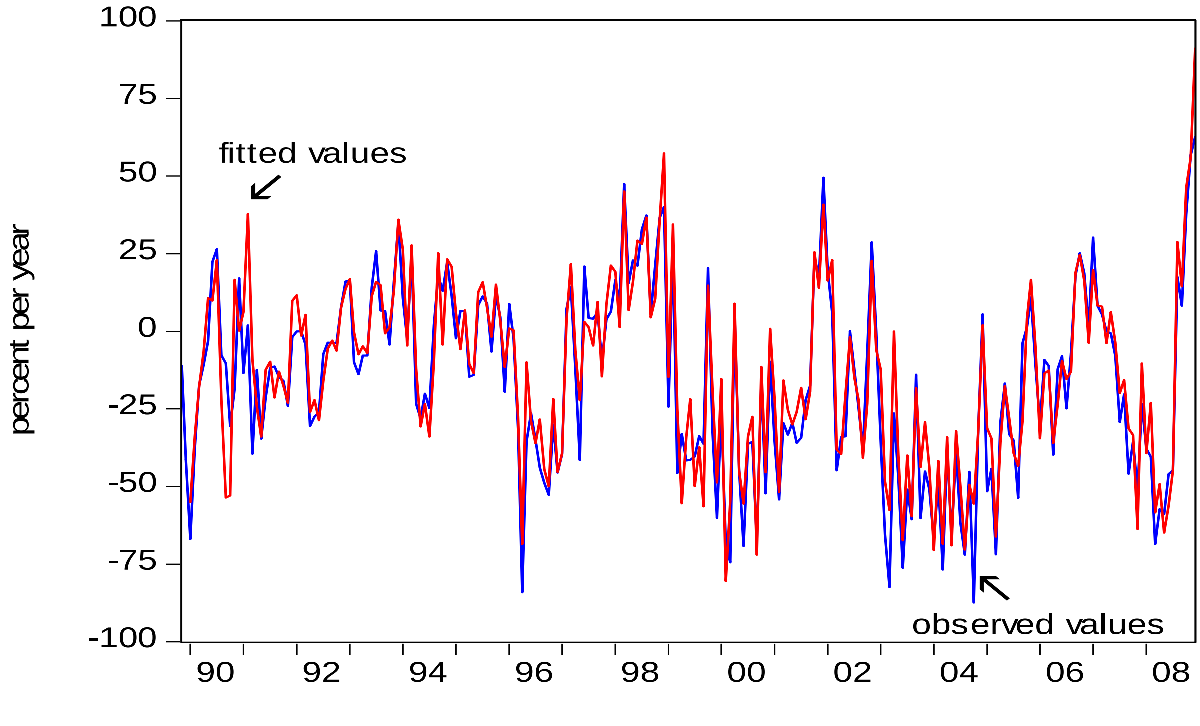

Figure 5 : observed and fitted values of the 12-month ahead expected change in oil price