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Commodities inventory effect

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Abstract

Asymmetric GARCH models were developped for equity stocks to take into account the larger response of the conditional variance to negative price shocks. We show that these asymmetric GARCH models are also relevant for modelling commodity prices. Contrary to the equity case, positive shocks are the main contributors to the conditional variance of commodity prices. The theory of storage, by relating the state of the inventories of a commodity to its conditional variance, is a serious candidate to explain the phenomenon, as positive price shocks for commodities usually serve as proxies for the deterioration of the inventories. We find that this inverse leverage effect, or "inventory effect", is relatively robust, for different subsamples, for diverse types of commodities and for different ways of specifying the asymmetry, though weaker than the leverage effect for equity stocks. Appropriately specifying the asymmetric conditional variance of commodities could improve risk management, hedging strategies or Value-at-Risk estimates. Incidentally, the inventory effect sheds some new light on the debate about the origin of the leverage effect.

Keywords: GARCH, asymmetries, leverage effect, inventory, commodities, Value-at-Risk.

JEL Classification: C22, G13, Q14

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1 Introduction

There has not been radical changes in the commodity pricing theories over the last 50 years, only some adjustments to the theory of storage. This field now raises a renewed interest for three reasons: (i) a significant commodity price boom occured from about 2003 untill mid-2008 - on that period, energy increased by more than 300%, grains and oils by more than 160%, precious metals by more than 200%; (ii) commodity derivatives occupy a much more important place than before - the Bank of International Settlement thus reports that the amounts outstanding of over-the-counter commodity derivatives (forward and options) are more than 13 trillions dollars as of June 2008, more than a doubling in two years, a much larger increase than for other OTC contracts ; (iii) the pressure on the demand side with the fast development of the BRIC countries, combined with the announced production peak of some commodities raises the questions of the occurence of potential stock-outs.

Our contribution relates to commodities and to the applicability of models allowing for asymmetric volatility responses to positive and negative shocks. Such an asymmetry is well known and widely documented for equity stocks. Equity stocks volatility usually reacts more to negative shocks than to positive ones. The traditional interpretation is that the deterioration of debt-to-equity ratio, consecutive to a downward movement of the stock, increases the risk of bankruptcy, and thus the nervosity of the markets. This argument is specific to equity stocks and cannot be extended to commodities. We show that there is another effect, specific to commodities, by which a price increase gives way to more volatility than a negative shock. Based on the theory of storage, an economic interpretation for commodities is that an increase in price potentially indicates a deterioration of the commodity inventories. A positive price shock may thus indicate an increasing probability of commodity stock-out. The phenomenon is thus inverse to the leverage effect, and could be more appropriately called inventory effect.

We document the inventory effect by studying the behaviour of specific commodities (metals, oilseeds, softs, fibres, grains, energy) and of commodity indexes. We use asymmetric GARCH models in view to capture the inventory effect such as the GJR-GARCH model of Glosten, Jagannathan, and Runkle (1993) and the EGARCH model of Nelson (1991). We also compare our results for different distributions, reiterate the estimates over two subsamples and find that the commodity inventory effect remains robust though weaker than the equity leverage effect.

The existence of the commodity inventory effect could have some implications regarding risk management. To illustrate this, we propose an application where we test whether an appropriate modelling of the commodity prices improves significantly Value-at-Risk (VaR) evaluations. Based on Kupiec (1995), we find that taking the inventory effect into account improves the VaR estimates. A careful investigation of the inventory effect is by consequence relevant before modelling the price of a commodity.

The existence of the inventory effect also brings some new evidence in the debate about the origins of the so-called "leverage" effect. Indeed, the traditional explanation, related to the "leverage", has recently been questioned (Figlewski and Wang (2002) and Hens and Steude (2009)). The inventory effect tends to weaken the new theories explaining the leverage effect.

This paper is structured as follows. Section 2 introduces the leverage effect characterizing equity prices and the GARCH models designed to capture this asymmetry. Section 3 examines the commodity pricing theory and identifies the potential source of asymmetry. Section 4 presents the empirical method, the dataset and the results relative to the presence of an inventory effect. In Section 5, a VaR application is proposed to test whether the inventory effect has a significant impact. Finally, Section 6 offers some discussion and concludes.

2 Capturing the leverage effect

GARCH models were initiated by Engle (1982) and Bollerslev (1986) in the eighties to capture the time varying volatility of macroeconomic and financial series. The models were extended in the nineties so that we now face a genuine "ARCH-mada" of models (see Terasvirta (2006), Bollerslev (2008) for some review in a univariate framework, Bauwens, Laurent, and Rombouts (2006) and Silvennoinen and Terasvirta (2008) in the multivariate one). The GARCH family models are specified as follows:

$$
\begin{aligned}
y_t &= \mu_t(\eta) + \epsilon_t \\
\mu_t &= E(y_t|\Omega_{t-1}) \\
\epsilon_t &= z_t \sigma_t(\eta) \\
z_t &\rightarrow i.i.d. \quad D(0,1) \\
\sigma_t^2 &= E(\sigma_t^2|\Omega_{t-1})
\end{aligned}
$$

where y_t is the raw series, μ_t is its conditional mean, η is a vector of unknown parameters, ϵ_t is the error term, σ_t^2 is the conditional variance, z_t is the standardized error, identically and independently distributed with mean zero and unit variance, and Ω_{t-1} is the information set at time t-1. GARCH models thus differ in the way that $E(\sigma_t^2|\Omega_{t-1})$ is specified. The most common specification is the GARCH(1,1) where $E(\sigma_t^2|\Omega_{t-1}) = \omega + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2$.

Among the GARCH models, some are developed to cope with the characteristic, originally put forward by Black (1976), that the increase in volatility of equity stocks is usually larger when the returns are negative than when they are positive. The traditional explanation of this asymmetry is related to the financial structure of the equity stocks. Falling returns give rise to a deterioration of the debt-to-equity ratio, which raises the probability of a default. This is the reason why the effect is called "leverage" effect. Some common models capturing this asymmetry are the GJR-GARCH of Glosten, Jagannathan, and Runkle (1993) and the EGARCH of Nelson (1991), among others. They respectively specify the conditional variance as follows:

$$
\begin{aligned}
\sigma_t^2 &= \omega + \alpha\epsilon_{t-1}^2 + \gamma S_{t-1}^- \epsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \\
log(\sigma_t) &= \omega + \beta log(\sigma_{t-1}) + \theta_1\epsilon_{t-1} + \theta_2(|\epsilon_{t-1}| - E|\epsilon_{t-1}|)
\end{aligned}
$$

where S_{t-i}^- is a dummy variable with value 1 if ϵ_{t-1} is negative and 0 otherwise, γ is the parameter capturing the asymmetric effect in the GJR-GARCH model, θ_1 and θ_2 are the parameters capturing respectively the sign effect and the amplitude effect of past shocks in the EGARCH model. A positive γ, or a negative θ_1, means that a past negative return has a larger impact on conditional volatility than a past positive return of the same amplitude (the so-called leverage effect). We use the GJR-GARCH(1,1) and EGARCH(1,1) models in our empirical section. We present now the theory of storage where we point out a potential explanation of the phenomenon.

3 Theory of storage and inventory effect

The point of this section is to show that we can find in the theory of storage some sources of asymmetries explaining the inventory effect revealed through the asymmetric GARCH models. We first explain the theory of storage, then show the central role played by inventories and finally show how these inventories give way to asymmetries.

The classical theory of storage (Kaldor (1939) and Working (1949)) is based on the idea that there should be a cost-adjusted equivalence between buying a future contract on a commodity and buying directly the commodity and storing it. The costs associated with storing are diverse (insurance, warehouse, heat). Formally, $F_{t,T} - S_t = W_{T-t} > 0$ where S_t is the spot price of the commodity at date t, $F_{t,T}$ is the price at t of the future contract on the commodity with delivery at time T and W_{T-t} is the global cost of storage between date t and T. Such a market where futures prices are larger than spot prices is said to be in contango.

Futures prices are however not always larger than spot prices. In such a situation, markets are said to be in backwardation. It happens that storage gives a good opportunity to the agent having the commodity in its inventory. For example, in case of sudden oil-market disruption, oil market prices will abruptly rise. The agents with oil at their disposal will be in a position to benefit from it. There is therefore what is called a convenience yield equal to $C_t = S_t - F_{t,T} + W_{T-t}$, where C_t is the convenience yield. The convenience yield varies in time and is expected to rise when the markets are tight and the aggregated inventories are low.

The modernized version of the theory of storage (Deaton and Laroque (1992)) replaces the idea of convenience yield by the costs implied by a potential stock-out. While in the classical theory, an inventory holder benefits from a convenience yield, the modernized version considers that the benefit is related to the implications of a potential stock-out. In both approaches, inventories are the core concept and determine to which extent $C_t(I_t) = S_t - F_{t,T} + W_{T-t}$ deviates from 0, where $C_t(I_t)$ is the convenience yield or its equivalent under the modernized version of the theory and I_t is the level of the global inventories of this specific commodity.

The specificity of commodities in this context is that inventories by definition cannot be negative. This non-negativity constraint is the source of the asymmetry, explaining the inverse leverage effect. As shown empirically by Gorton, Hayashi, and Rouwenhorst (2007), the convenience yield is a decreasing, non-linear function of inventories. In other words, when inventories get tight, a further decrease in the inventories has a much larger impact on the price of the commodity than an increase in the inventories. The closer the potential stock-out, the larger the impact of the non-linearity.

We now bring the final piece of the explanation. In an ideal world, inventory data would be available and the theory could be tested. This direct-inventory approach (illustrated by Brennan (1958), Telser (1958) or more recently by Gorton, Hayashi, and Rouwenhorst (2007)) is however heavily weakened by the difficulty to define an appropriate scope for inventory data and by the difficulty to collect data about inventories as they are generally not exhaustively known. As a consequence, applied works often rely on various proxies such as monthly dummies (Fama and French (1987)), business cycles (Fama and French (1988)) or price shocks (Gorton, Hayashi, and Rouwenhorst (2007)). Price shocks are precisely the last piece of our puzzle. A price increase could indeed reveal that demand exceeds supply, and thus decreasing inventories.

The point of this research is not to provide an additional test of the theory of storage but to understand the phenomenon specific to commodities by which a positive return has a larger impact on the volatility than a negative return and to justify the relevance to use an asymmetric GARCH model. As a signal of the state of the inventories, positive price shocks reveal that inventories are tight and raise the volatility. Negative price shocks reveal that supply exceeds demand, which reduces volatility. This is precisely what we call the inventory effect. We now document empirically this inventory effect and check its robustness for different periods, commodities and specifications.

Table 1: Presentation of the series

Series	Description	Type	Unit Base
ALUM	LME-Aluminium 99.7% Cash USD/MT	Metals	Metric Tonne
NICK	LME-Nickel Cash USD/MT	Metals	Metric Tonne
ZINC	LME-SHG Zinc 99.995% Cash USD/MT	Metals	Metric Tonne
GOLD	Gold Bullion LBM USD/Troy ounce	Precious Metals	Troy Ounce
SILV	Silver Fix LBM Cash Cents/Troy ounce	Precious Metals	Troy Ounce
CORN	Corn No.2 Yellow Cents/Bushel	Grains	Bushel
WHEAT	Wheat, No.2 Hard (Kansas) Cts/Bushel	Grains	Bushel
COTT	Cotton,1 1/16Str Low -Midl,Memph Cts/Lb	Fibres	Pound
COFF	Coffee-Brazilian (NY) Cents/lb	Softs	Pound
SOYB	Soyabeans, No.1 Yellow Cts/Bushel	Oilseeds	Bushel
BRENT	Crude Oil-Brent Current Month FOB USD/BBL	Energy	Barrel
GAS	Gas Oil-EEC CIF Cargos NWE USD/MT	Energy	Metric Tonne
GSCI	S&P GSCI Commodity Spot Index	Index	Points
LMEI	London Metal Exchange Index	Index	Points
CCI	Equal Weight Reuters CCI TR Index	Index	Points
NSDQ	Nasdaq Composite Price Index	Index	Points

Notes. "LME" holds for London Metal Exchange, "MT" for Metric Tonnes, "SHG" for Special High Grade, "LBM" for London Bullion Market, "lb" for pound-mass, "FOB" for Free on Board, "CIF" for Cost, Insurance and freight included, "BBL" for oil barrel, "CCI" for Continuous Commodity Index" and "GSCI" for Goldman Sachs Commodity Index.

4 Testing the inventory effect

We test the inventory effect on a set of fifteen commodity prices series. The dataset, available on Datastream, covers the period from 3rd January 1994 to 31st December 2009, so 16 years with 4174 data per series. Our dataset includes three well known commodity indexes (Goldman Sachs Commodity index, the London Metal Exchange Index and the Reuters CCI Index), three metals (Aluminium, Nickel and Zinc), two precious metals (Silver and Gold), two grains (Corn and Wheat), one fibres (Cotton), one soft (Coffee), one oilseeds (Soyabeans) and two energy (Brent and Gas). For comparison purposes, we include in all our estimates an equity index (Nasdaq). Details of the series are reported in table 1. The commodities were selected for their availability on a daily basis over a sufficiently long period and for their market liquidity. The series in level and returns are presented in figures 1 to 8. The cumulative growth after 8 years (2002) and 16 years (2010) is presented for each series in figure 9.

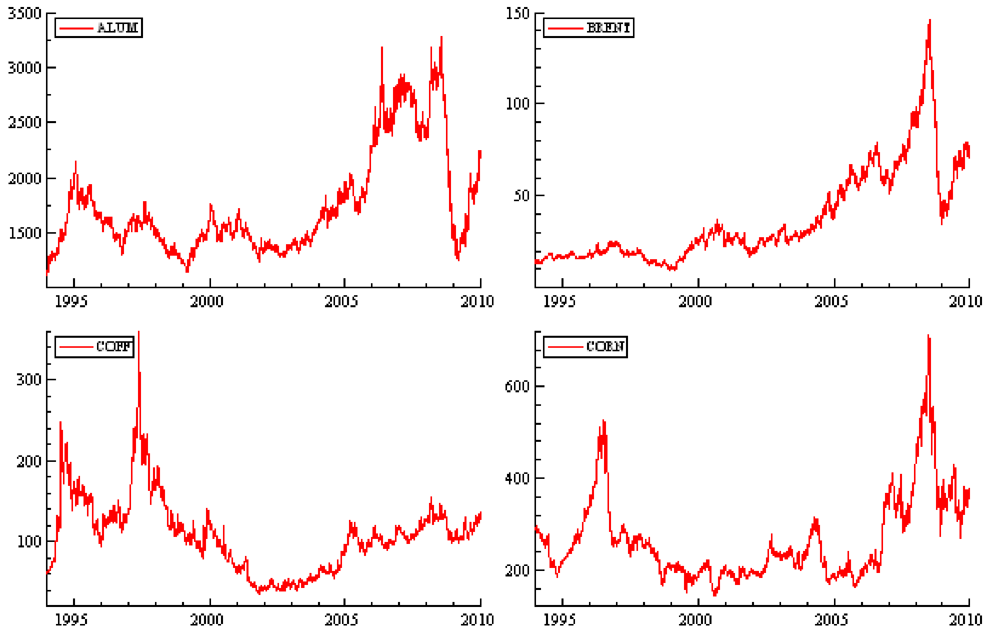

Figure 1: Price series of ALUM, BRENT, COFF and CORN

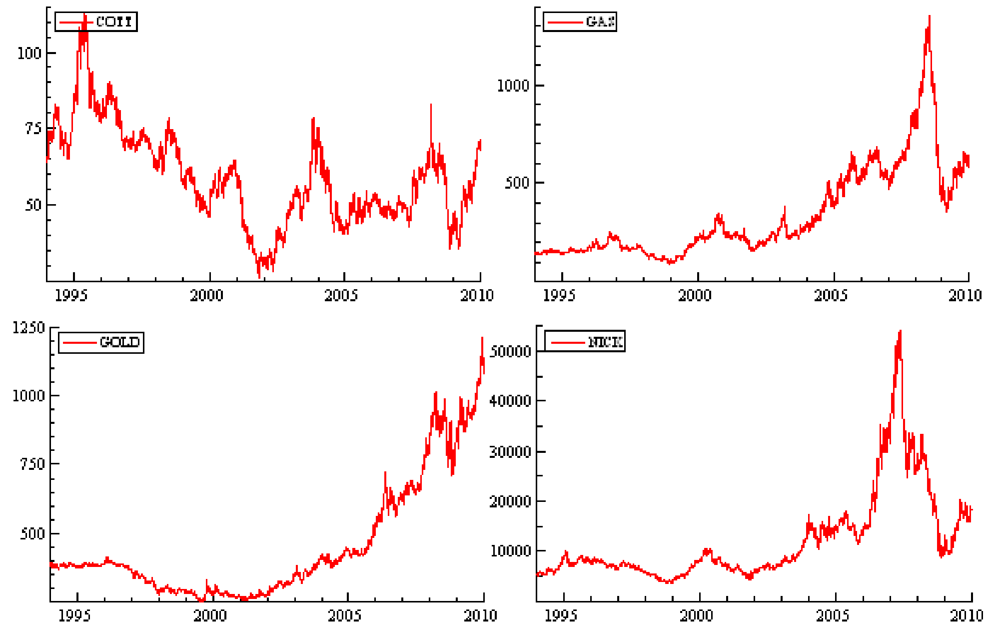

Figure 2: Price series of COTT, GAS, GOLD and NICK

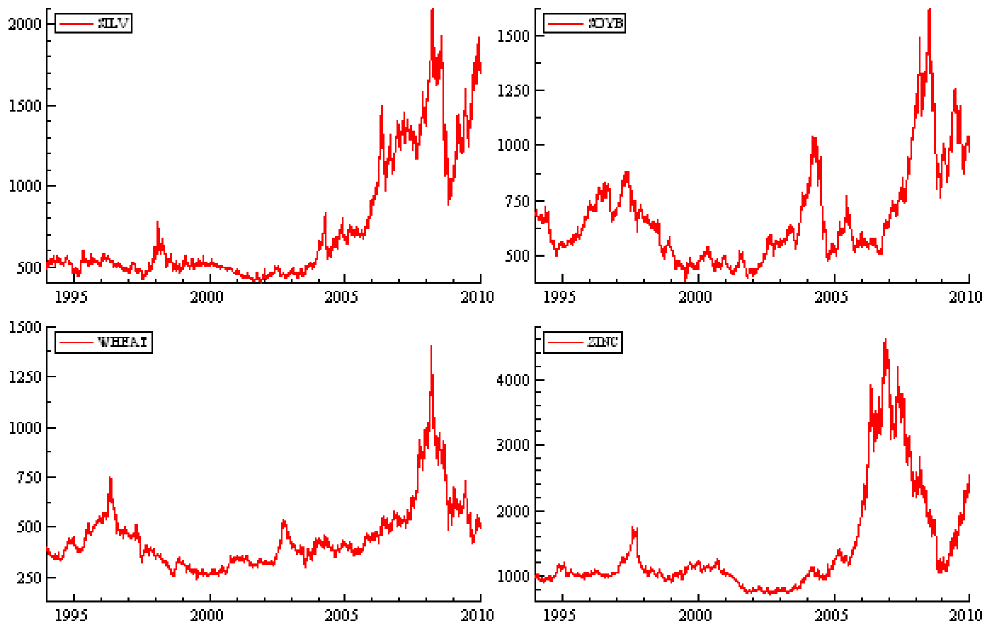

Figure 3: Price series of SILV, SOYB, WHEAT and ZINC

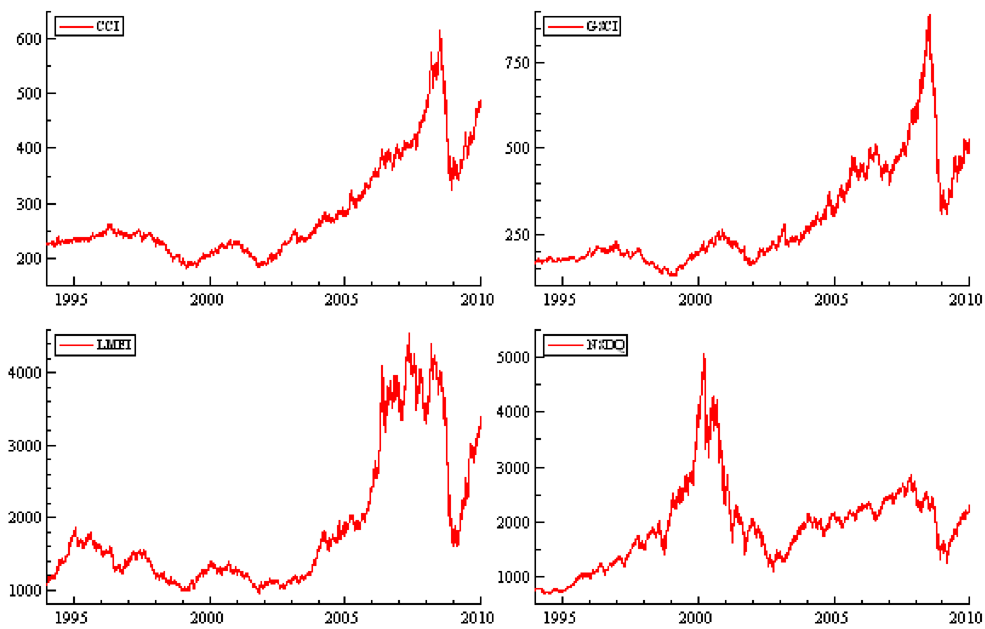

Figure 4: Price series of CCI, GSCI, LMEI and NSDQ

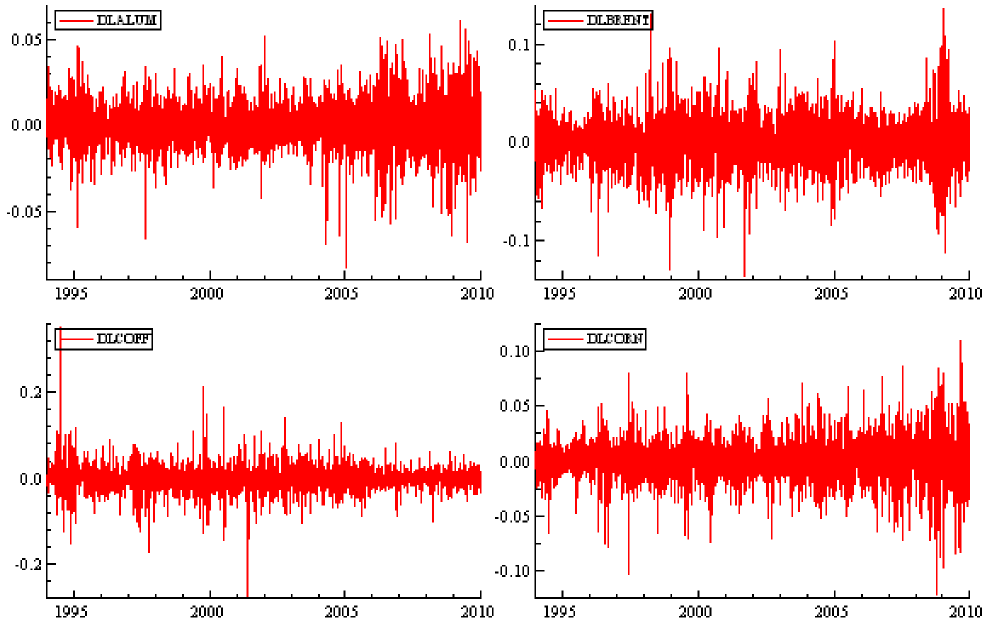

Figure 5: Return series of ALUM, BRENT, COFF and CORN

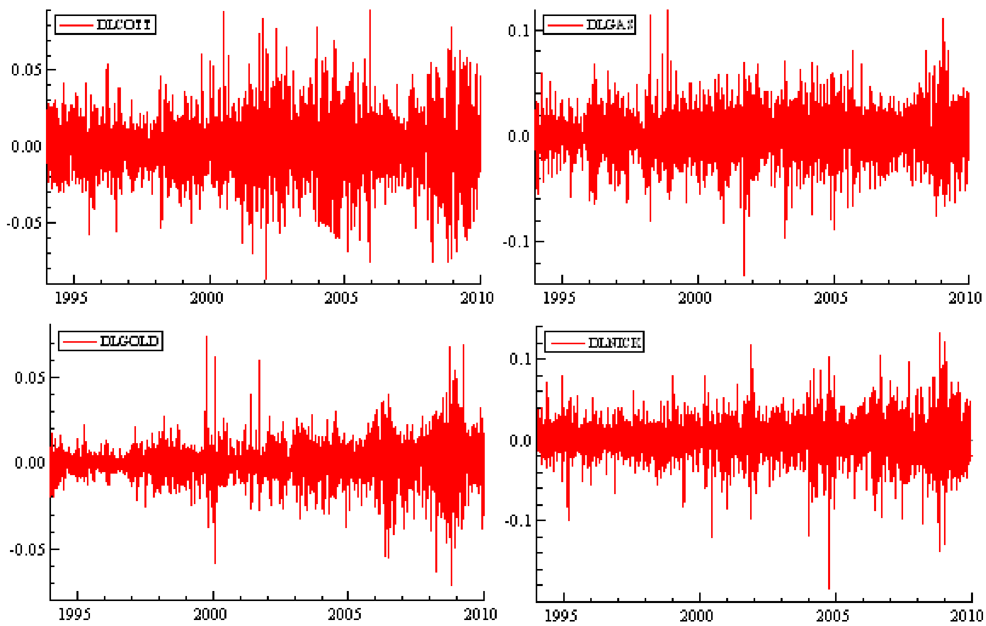

Figure 6: Return series of COTT, GAS, GOLD and NICK

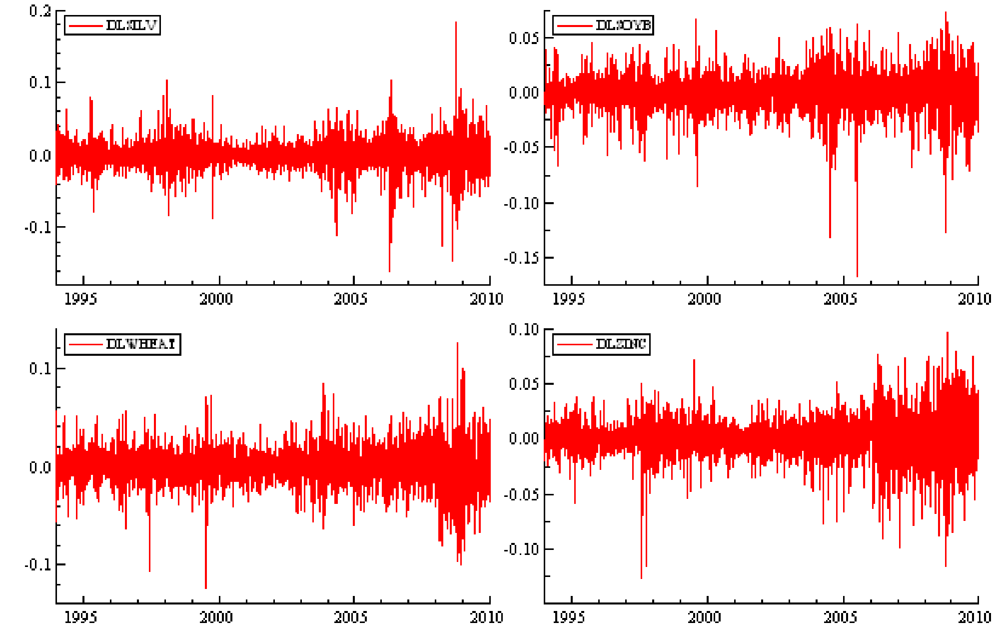

Figure 7: Return series of SILV, SOYB, WHEAT and ZINC

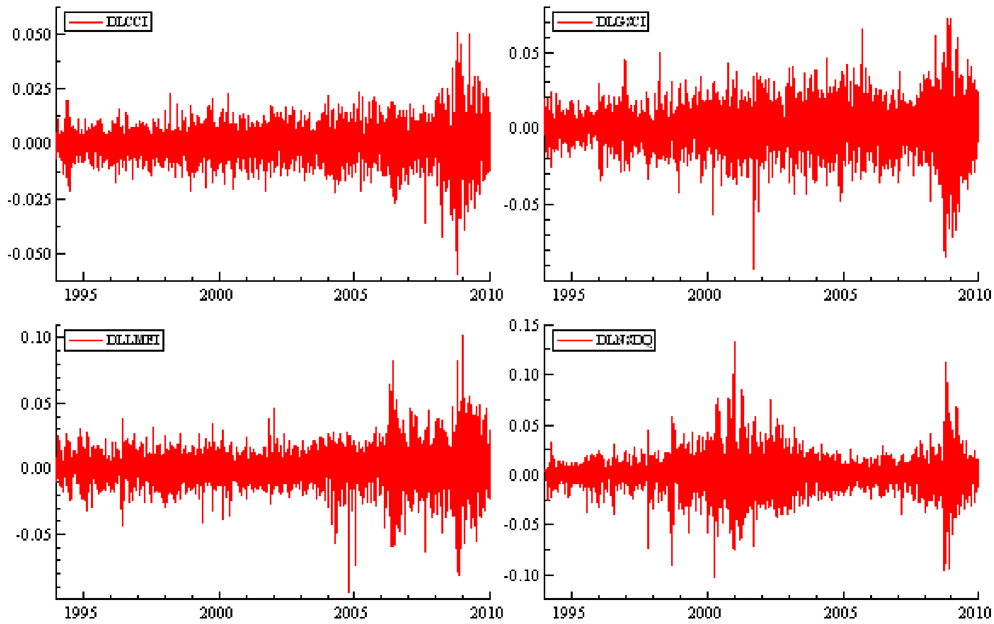

Figure 8: Return series of CCI, GSCI, LMEI and NSDQ

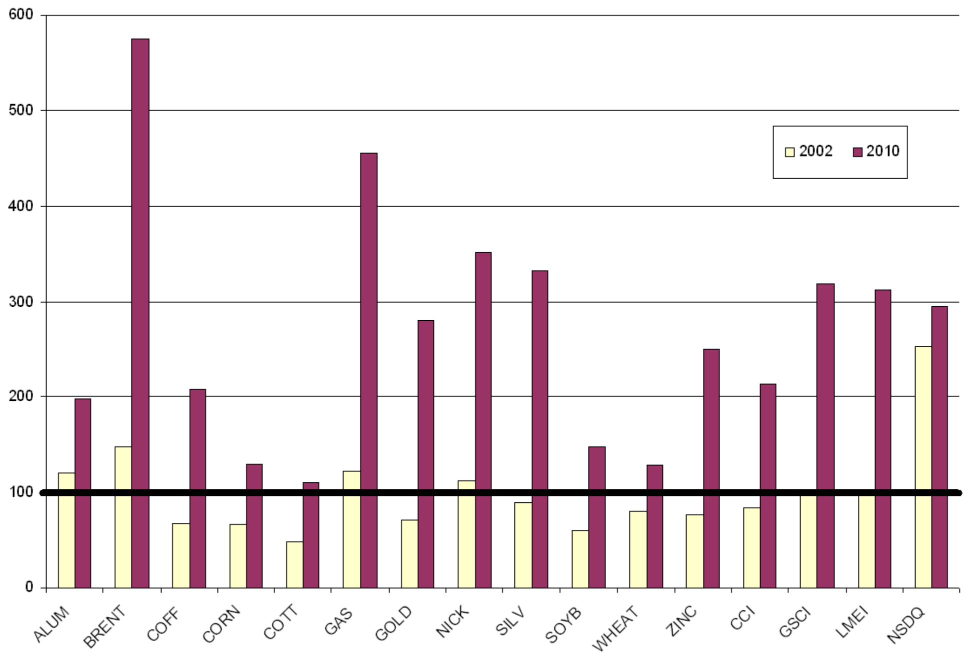

Figure 9: Commodity prices after 8 years and 16 years (base 1994=100)

Since price series are non stationary (on the basis of augmented Dickey-Fuller tests reported in table 2), we transform the series, by taking the difference of the log, to work with returns. We observe in the descriptive statistics detailed in table 3 that average returns over 16 years are all positive and to some extent close to each other. If we annualize the returns we find average growth of 0% to 12% per year. It is worth noting that, unlike some previous results (Gorton and Rouwenhorst (2004), Gorton, Hayashi, and Rouwenhorst (2007) and Deaton and Laroque (1992)), most of our series exhibit a significant negative skewness (cotton, coffee, gas, gold and wheat excepted). Positive skewness is usually found in commodity series as an implication of the theory of storage where positive spikes exceed in frequence and amplitude negative spikes. Without surprise, we also find that all series are leptokurtic. The negative skewness, which is not so exceptional for commodities (Deaton and Laroque (1992)), and the leptokurtosis indicate that it could be relevant to estimate our models with a skewed-Student distribution (Lambert and Laurent (2001)).

To test and document the inventory effect, we first remove autocorrelations in the series (cf their respective correlograms in figure 10). We therefore adjust an autoregressive filter (up to lag 5) for the mean equation $\mu_t(\eta)$ based on the Schwarz criterion. Filters for the mean

Table 2: Augmented Dickey-Fuller tests

Series	# dlags	trend	t-value	UR
ALU	2	no	-1.78	yes
BRENT	15	yes	-2.93	yes
COFF	7	no	-1.88	yes
CORN	17	no	-1.94	yes
COTT	2	no	-2.11	yes
GAS	0	yes	-2.35	yes
GOLD	17	yes	-0.98	yes
NICK	5	no	-1.28	yes
SILV	17	yes	-1.94	yes
SOYB	14	no	-1.61	yes
WHEAT	9	no	-1.75	yes
ZINC	4	no	-0.81	yes
CCI	18	yes	-1.45	yes
GSCI	15	yes	-2.35	yes
LMEI	4	no	-0.47	yes
NSDQ	13	no	-2.00	yes

Notes. Dickey-Fuller tests performed on the logarithmic series. Specification with trend and constant: 5%=-3.41 and 10%=-3.97. Specification with constant but no trend: 5%=-2.86 and 1%=-3.43. " #dlags" refers to the augmented-lag structure of the specifications, based on the Akaike information criterion. "UR" holds for "unit root".

equation and diagnosis tests about autocorrelation and heteroskedasticity of the residuals are detailled in table 4). We find that the autocorrelation is removed from each series at 5%. We also find that all the series have highly significant heteroskedasticity. We note that the filter of some series contains no lag. This prevents the model to capture the skewness of the series (see He, Silvennoinen, and Tersvirta (2008)). This is an additional motivation to check robustness of our estimates with skewed-distribution.

We then estimate a GJR-GARCH model on the filtered series. We include in the specification a constant in the variance equation and a Gaussian distribution ("specification 1" in table 5). To check for robustness, we also reiterate the estimates with a skewed-Student distribution to account for the non-normality of the series ("specification 2" in table 5). We also estimate the GJR-GARCH(1,1) model with a Gaussian distribution on half samples 1994-2001 ("specification 3" in table 5) and 2002-2009 ("specification 4" in table 5). We finally check the robustness of the inventory effect to the model, by estimating on the full sample an EGARCH(1,1) with a Gaussian distribution ("specification 5" in table 5).

Table 3: Descriptive statistics for commodity returns

Series	Mean	Std. Dev.	Skewness	Excess Kurtosis
ALUM	0.0164	1.31	-0.25 (0.00)	2.76 (0.00)
BRENT	0.0419	2.29	-0.09 (0.02)	2.74 (0.00)
COFF	0.0175	2.64	0.70 (0.00)	18.63 (0.00)
CORN	0.0061	1.82	-0.22 (0.00)	3.63 (0.00)
COTT	0.0024	1.82	0.04 (0.27)	2.34 (0.00)
GAS	0.0363	2.09	-0.02 (0.69)	2.17 (0.00)
GOLD	0.0247	0.99	-0.02 (0.57)	7.29 (0.00)
NICK	0.0301	2.30	-0.09 (0.02)	4.25 (0.00)
SILV	0.0288	1.87	-0.30 (0.00)	8.56 (0.00)
SOYB	0.0093	1.62	-0.79 (0.00)	6.79 (0.00)
WHEAT	0.0060	1.81	0.02 (0.60)	4.19 (0.00)
ZINC	0.0219	1.78	-0.33 (0.00)	4.71 (0.00)
CCI	0.0181	0.77	-0.31 (0.00)	5.24 (0.00)
GSCI	0.0278	1.42	-0.22 (0.00)	3.19 (0.00)
LMEI	0.0273	1.37	-0.16 (0.00)	4.67 (0.00)
NSDQ	0.0259	1.67	-0.02 (0.55)	5.30 (0.00)

Notes. Statstics on the series in return. 4173 observations. Mean and standard deviation are multiplied by 100 for readability. P-values are in parentheses.

The most striking result for the first column of table 5 is the negativity of the parameter estimates that we can observe for most commodities, excepted Brent, Cotton and Corn. The parameter is the asymmetry coefficient γ of the GJR-GARCH(1,1) specification. Its negativity indicates the presence of an inventory effect for most of the commodities. The inventory effect is significant for aluminium, coffee, gold, silver, soybean, wheat and zinc. Though not generalized to all commodities, the results indicate that there is a significant inverse leverage effect for some commodities, no matter their characteristics (metal, precious metal, cereal or soft). We also find that the size of the effect, comprised between 0.02 and 0.06 in absolute value is smaller than 0.09 for equity. Modifying the model specification by using a skewed-Student distribution (Lambert and Laurent (2001)), we obtain similar results with 12 negative coefficients (for 15 commodities). Estimates of the model with Student distribution gave similar results (not reported here). When we reiterate the estimate on sub-samples of 8 years, respectively 1994-2001 and 2002-2009, we obtain equivalent results though slightly weaker (see columns 4 and 5 in table 5). The inventory effect seems less perceptible on shorter periods. We finally reiterate the estimation with the EGARCH(1,1) model and find similar results, though weaker. The asymmetry coefficient in the EGARCH(1,1) model, θ_1, is expected to be positive in the presence of an inventory effect. We find that the inventory effect is positive and significant for 4 commodities (coffee, gold, silver and soybean). We

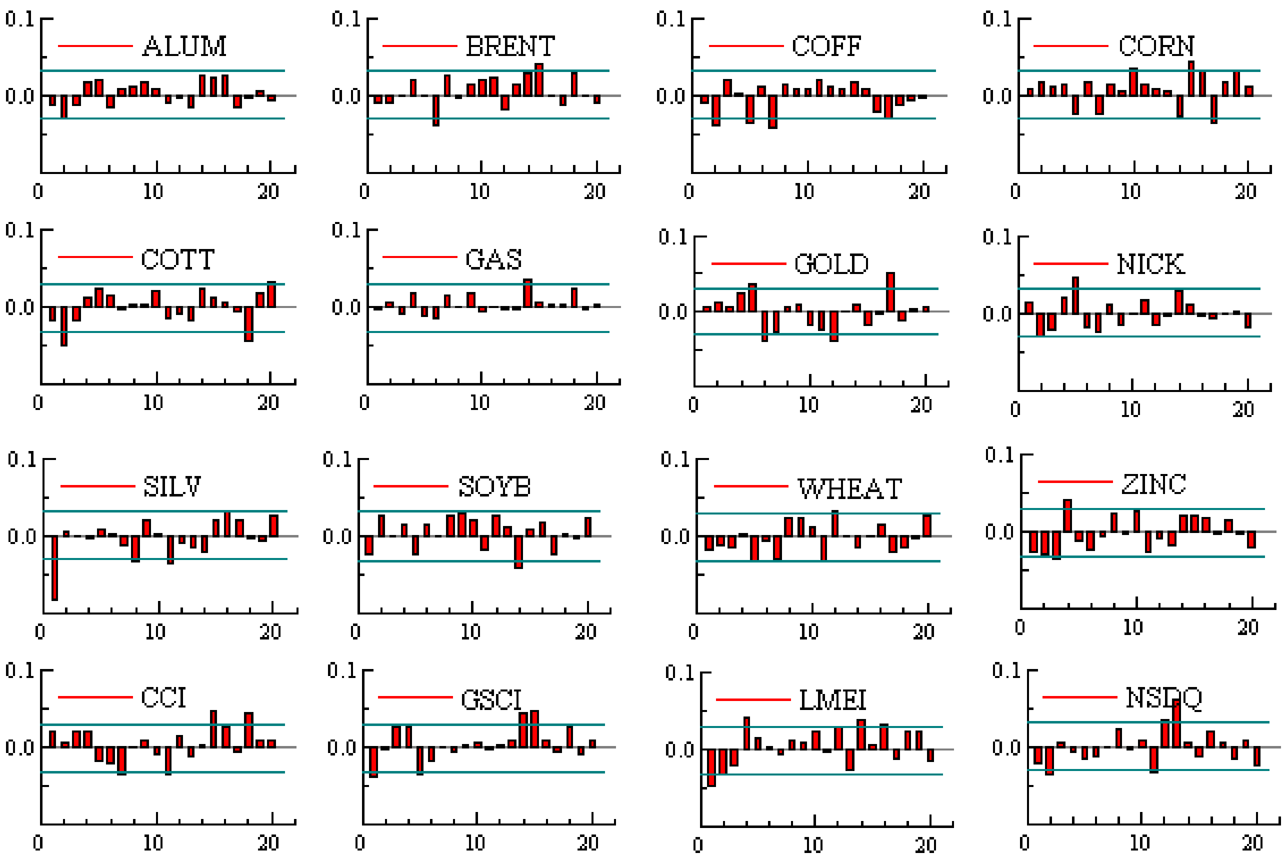

Figure 10: Autocorrelogram of the commodity return series

conclude from this section that there is an inventory effect specific to commodities (metals, cereals, soft), but weaker and less robust than the leverage effect documented for the equity prices.

5 Value-at-Risk application

Appropriately taking into consideration the leverage effect for equity prices can considerably improve value-at-risk estimates, and risk management in general. In this section we investigate the potential benefit of taking into account the inventory effect for commodities in the conditional variance specification. We start by realizing a risk management analysis by estimating in-sample VaR for investing in commodities. The VaR measures the expected maximum losses over an investment period given a certain probability α. In other words, losses over that period will be smaller than the VaR with a probability $1 - \alpha$.

Table 4: Autoregressive filtering of the mean equation, and autocorrelation/heteroskedasticity tests on the residuals

Series	Lags of the AR filter	AR test $F(2,.)$	ARCH test $F(1,.)$
ALUM	2	0.95 (0.39)	70.6 (0.00)
BRENT	-	0.42 (0.65)	99.3 (0.00)
COFF	2;5	1.96 (0.14)	42.5 (0.00)
CORN	-	0.60 (0.55)	164.0 (0.00)
COTT	2	1.08 (0.34)	66.3 (0.00)
GAS	-	0.09 (0.91)	31.0 (0.00)
GOLD	5	0.52 (0.60)	122.3 (0.00)
NICK	5	2.08 (0.12)	153.9 (0.00)
SILV	1	0.66 (0.52)	58.3 (0.00)
SOYB	-	2.82 (0.06)	42.2 (0.00)
WHEAT	5	0.60 (0.55)	277.8 (0.00)
ZINC	3; 4	2.95 (0.05)	151.2 (0.00)
CCI	-	1.03 (0.36)	67.2 (0.00)
GSCI	1; 4; 5	0.31 (0.73)	87.3 (0.00)
LMEI	1;2;4	1.80 (0.17)	131.8 (0.00)
NSDQ	2	1.21 (0.30)	206.9 (0.00)

Notes. Autoregressive filter (up to 5 lags) estimated by OLS on the series in return. "AR" test is the Lagrange-Multiplier test of 2nd order correlation in the residuals. "ARCH" test is the test of 1st order autocorrelation in the squared residuals. P-values are in parentheses.

As the inventory effect is related to the asymmetry in the series, and especially an augmented variance when returns are positive, we analyze the right side of the distribution by examining the VaR for a short trading position (Giot and Laurent (2003)). A short position is a position where a trader sells an asset borrowed from a third party and later buys back the asset to give it back to the lender. This short trader loses money if the price of the asset increases. The short trader is interested by the right tail of the return distribution.

Since we aim to compare a model capturing the inventory effect with a model not capturing it, we select the commodity series for which the inventory effect is significant (based on table 5) and follow the methodology provided in the previous section to estimate value-at-risks with both GJR-GARCH(1,1) and pure GARCH(1,1) models on the full sample. Our specification includes a constant in the variance equation and is based on a Gaussian distribution. To compare the respective performance of the specifications, taking (GJR) or not taking (GARCH) into consideration the inventory effect, we rely on the p-values of the test developed by Kupiec (1995). This test allows us to decide whether the failure rate (percent of in-sample potential

Table 5: Summary table of the inventory effect

Specif.	1	2	3	4	5
Sample	1994-2009	1994-2009	1994-2001	2002-2009	1994-2009
Model	GJR	GJR	GJR	GJR	EGARCH
Distr.	Gaussian	Skewed-Student	Gaussian	Gaussian	Gaussian
Coef.	γ	γ	γ	γ	θ_1
ALUM	-0.0215 (0.05)	-0.0162 (0.11)	-0.0879 (0.00)	-0.0363 (0.07)	0.0162 (0.16)
COFF	-0.0555 (0.00)	-0.0817 (0.01)	-0.0751 (0.10)	-0.0493 (0.00)	0.0974 (0.00)
GOLD	-0.0530 (0.00)	-0.0455 (0.00)	-0.0445 (0.01)	-0.0284 (0.16)	0.0511 (0.00)
SILV	-0.0351 (0.01)	-0.0498 (0.00)	-0.0680 (0.00)	-0.0313 (0.30)	0.0337 (0.06)
SOYB	-0.0518 (0.00)	-0.0389 (0.00)	-0.0409 (0.07)	-0.0038 (0.81)	0.0208 (0.02)
WHEAT	-0.0225 (0.07)	-0.0367 (0.00)	-0.0348 (0.05)	-0.0166 (0.16)	0.0125 (0.41)
ZINC	-0.0268 (0.01)	-0.0175 (0.02)	-0.0066 (0.75)	0.0076 (0.61)	0.0199 (0.21)
GAS	-0.0018 (0.88)	-0.0142 (0.14)	0.0628 (0.25)	-0.0222 (0.16)	-0.0010 (0.89)
NICK	-0.0072 (0.49)	0.0002 (0.98)	-0.0159 (0.43)	-0.0003 (0.98)	-0.0010 (0.96)
CCI	-0.0053 (0.47)	-0.0071 (0.37)	-0.0268 (0.13)	0.0172 (0.21)	-0.0005 (0.94)
GSCI	-0.0090 (0.37)	-0.0128 (0.13)	0.0294 (0.16)	-0.0115 (0.39)	-0.0019 (0.75)
LMEI	-0.0050 (0.58)	-0.0043 (0.59)	-0.0007 (0.97)	0.0482 (0.00)	-0.0001(0.98)
BRENT	0.0234 (0.05)	0.0252 (0.01)	0.0161 (0.49)	0.0108 (0.59)	-0.0241 (0.06)
CORN	0.0052 (0.72)	-0.0087 (0.53)	-0.0004 (0.97)	0.0052 (0.68)	-0.0224 (0.17)
COTT	0.0023 (0.79)	0.0087 (0.34)	0.1081 (0.00)	0.0754 (0.00)	0.0035 (0.48)
NSDQ	0.0909 (0.00)	0.0944 (0.00)	0.1053 (0.00)	0.0805 (0.00)	-0.0571 (0.00)

Notes. Maximimum likelihood estimates on the filtered return series. The filters of the mean equations are detailed in table 4. We also use specific filters for the half samples. The γs are the asymmetry coefficients of the GJR-GARCH(1,1) models and the θ_1s are the asymmetry coefficients of the EGARCH(1,1) models. P-values based on robust standard errors are in parentheses. For robustness check, we also estimated mean and variance coefficients together in a one-step procedure. Results are similar and are available on request. We also estimated the model with the Student distribution. Results are highly similar to the skewed-Student distribution ones and are available on request.

losses exceeding the forecasted value-at-risk) is significantly different from the significance level, α. If the p-values increase when we use the GJR-GARCH(1,1) specification, it means that taking into account the inventory effect improves the quality of the VaR estimates and is thus valuable in term of risk management.

We find, and report in table 6, that taking into account the leverage effect improves the VaR estimates for aluminium, coffee, gold, wheat and zinc according to the Kupiec (1995) tests when the significance level of the VaR is 5%, and of aluminium, silver, soybean and zinc when the significance value is 1%. These results are not generalizable to all commodities since we find for example that the GJR model is not preferred for soybean when the VaR significance level is 5%. Though certainly weaker than those documented for equity indices, these results illustrate that considering asymmetric garch models for commodity returns is a relevant preliminary step.

Table 6: VaR - Comparison of GARCH(1,1) and GJR-GARCH(1,1) based on Kupiec test for series affected by the inventory effect

Specification	**GARCH(1,1)**		**GJR-GARCH(1,1)**		**Best specification**	
p-values	0.95	0.99	0.95	0.99	0.95	0.99
ALUM	0.301	0.007	0.374	0.048	GJR	GJR
COFF	0.184	1.73e-04	0.336	3.35e-05	GJR	GARCH
GOLD	0.122	3.35e-05	0.210	5.74e-06	GJR	GARCH
SILV	0.077	4.84e-04	0.077	0.003	-	GJR
SOYB	0.065	0.122	0.018	0.267	GARCH	GJR
WHEAT	0.192	1.18e-07	0.591	1.18e-07	GJR	-
ZINC	0.501	0.012	0.597	0.024	GJR	GJR

Notes. The Kupiec (1995) test estimates whether the failure rate (percent of in-sample potential losses exceeding the forecasted value-at-risk) is significantly different from the significance level, α. The reported values are p-values for the test perfomed on the right-tail of the distribution. Estimates are based on Gaussian distribution on the full sample. The larger the p-value, the more appropriate the model. The last two columns indicate the model for which the p-values are the larger.

6 Discussion and conclusion

Though the asymmetric models have generally been developed for equity series to account for the leverage effect, we show that commodities exhibit some asymmetry in their conditional variance as well. We show that this asymmetric effect for commodities has an opposite sign to the equity case. We also propose to this asymmetry an explanation related to the theory of storage and to the non-negativity constraint characterizing the inventories. Price variations indeed can proxy the level of inventories (Gorton, Hayashi, and Rouwenhorst (2007)). The larger the price increase, the more probable the inventory deterioration. This can explain why positive returns give way to larger increases of the volatility. Based on this explanation, we propose to label this inverse leverage effect as “inventory effect”.

We believe that this inventory effect should be taken into account to improve risk managements tools, such as VaR. We compared a model taking into consideration the inventory effect and a model not capturing it. Based on Kupiec (1995) tests we could illustrate an improvement in the VaR performances. Though relatively significant for many commodities, we observe that the inventory effect is weaker than its equity counterpart, the leverage effect.

The leverage effect is named “leverage” due to the traditional explanation relating the capital structure to the volatility. A price decrease indeed gives rise to a deterioration of the debt-to-equity ratio, rising the probability of a default. This can reasonably explain why the increase in volatility is larger when returns are negative. However, this traditional explanation of negative correlation of stock returns and volatility has recently been questioned. Indeed, Figlewski and Wang (2002) investigate the relationship of the market volatility and the debt-to-equity ratio, and fail to establish any clear relation. They conclude that the asymmetry is probably more related to a down-market effect than to a leverage effect. In addition, Hens and Steude (2009) propose a controled experiment where they test the relevance of the leverage explanation. They find that the leverage effect is also observed on markets where the underlying assets do not exhibit any financial leverage. They also propose two explanations: (1) after a downturn of markets, the expected future return increases, as well as the volatilty; and (2) the risk aversion of traders decreases after a downturn of the markets. Indeed , these approaches are plausible candidates to explain the "leverage" effect.

The inventory effect tends to shed some new light on this debate, though not being conclusive. The down-market argument and both the explanations proposed in Hens and Steude (2009) should actually also hold for commodities. This is not the case. The inventory effect gives an opposite sign to the "leverage effect". This tends certainly to weaken their arguments and to favour the traditional explanation based on an argument specific to equity (such as the leverage).

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