# Credit Risk and mild explosivity of Credit Default Swaps in the Corporate Energy Sector

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**Abstract**

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This paper analyzes the determinants of credit risk in the energy sector. We use CDS spreads of energy corporations as well as CDS energy sectorial indexes and assess whether credit risk in energy companies can be linked to the crude oil price fundamental and to other exogenous financial variables. Using the multiple bubble methodology proposed by Phillips Shi and Yu (2015 *International Economic Review* 56 (4), 1043-1133) we concentrate on bubble characteristics around the 2014-2016 crude oil price collapse, and associate mild explosivity in CDSs with the corresponding fundamental forces via a series regressions applied to time changing autoregressive coefficients.

Keywords: CDS, CDS indexes, mild explosivity, crude oil price, corporate debt, CAPEX Taper Tantrum.

## 1. Introduction

In this paper, we analyze the determinants of credit risk in the energy sector in terms of the price behavior of its debt collateral the crude oil price as well as other financial variables. We consider for this purpose the time series properties of crude oil futures prices and the 10 year US real bond yield rate as well energy corporate balance sheet measures focusing on the effects of the 2013 taper announcement.

Over the 2013-2016 period, the US and European economies saw energy companies defaulting on hundred billions worth of debt, signaling a significant increase in the degree of financial stress led by US oil and gas companies. Low oil prices left many energy corporates with challenging debt loads causing them to default at an extraordinary rate. As a result, Credit Default Spreads (CDSs thereafter) of leading energy corporates exhibited episodes of abrupt spread increases not seen since the 2007-2008 Global Financial Crisis (GFC) thereafter. CDS premia of the main global corporates such as Chevron or British Petroleum rose more than a fourfold in 2015. Energy sectorial CDS indexes also saw sharp increases in the aftermath of the tapering announcement and the collapse of energy prices. In this paper, we show that such behavior represents departures from the standard martingale model and associate the observed salient features with the corresponding fundamental forces.

There are a number of subsequent events that explain the rising tide of defaults in the energy sector. Industry experts suggest that the increase in financial stress emerged because investors reconsidered their exposure to companies borrowing heavily under the Quantitative Easing policies of the Federal Reserve Bank that suppressed interest rates. This contributed to increased capital flows into the energy sector under the risk-taking channel of the monetary policy in connection with high oil prices (see Liebig, 2018).

Indeed, in the spring of 2013, there was a surge in U.S. Treasury Yields, which resulted from the Federal Reserve´s tapering announcement, implying the gradual end of expansive monetary policies.  During the last quarter of 2014 crude oil prices collapsed in a way that was not consistent with the standard martingale assumption (see Figuerola-Ferretti, McCrorie and Paraskevopoulos 2019 and references therein) and the U.S. tapering process was eventually initiated in 2015.

In this paper we analyze the determinants of credit risk in energy corporates by looking at individual CDS as well as sectorial CDS indexes and their corresponding fundamentals.  In a first stage we use the multiple bubble methodology derived by Phillips Shi and Yu (PSY, 2015) for testing for mild explosivity seen as departures from trend value.  We then analyze recursive autoregressive estimates in a second stage via a series of time series and panel regressions between the CDSs and fundamental variables.  Regression results are used to evaluate three different hypotheses relating CDSs premia and their fundamental values.

The PSY methodology offers a statistically consistent basis upon which to date the start and collapse of mildly explosive episodes in financial time series. We show that CDS premia exhibited three main periods of mild explosivity during the last two decades that are closely related to the recent crude oils shocks documented in the literature and to changes in US monetary policy.  We additionally offer evidence of the credit channel theory of monetary policy by connecting credit risk of energy corporates and crude oil prices to balance sheet measures.

Figuerola-Ferretti McCrorie and Paraskevopoulos (FFMP, 2019) recently applied the PSY methodology to test for mild explosivity in crude oil prices. In their analysis they find that there was an explosive period in crude oil prices during the 2007-2008 oil price spike and a short negative such episode during the 2014 oil price decline. Assessing the role of fundamentals and other factors they show that, while there was a global economic activity factor which was decisive in explaining the 2008 bubble, the decline in 2014 was associated with supply side disruptions that took place after an OPEC meeting in late November 2014, in which the organization unexpectedly announced that it would not curtail output. FFMP provide robust evidence that helps to resolve a number of controversies regarding the recent 2014 crude oil price collapse given the lack of consensus in terms of the fundamental forces that underlined the recent slump. While the academic papers that analyze the behavior of the crude oil prices have mainly concentrated in considering demand and supply fundamentals as well as geopolitical forces (see Arezki and Blanchard 2014, Baffes et al. 2015 and Baumeister and Kilian 2016), the literature that looks at the relationship oil prices and credit risk is more limited. Domansky Kearns Lombardi and Shin (2015) found evidence showing the connection between oil and debt over the 1996-2014 period. In their paper, they capture the effect of the oil price variation in the financial structure of oil-related firms. Their main findings suggest that the price of oil is a proxy for the value of underlying assets underpinning corporate debt in the energy sector. The implication is that lower prices are expected to reduce profitability, while increasing default risk due to higher financing costs. In a related paper Lips (2018) use well level data to analyze empirically the relationship between the financial situation of oil and gas companies and production decisions. They illustrate the process by which increased investment activity financed with the extensive use of debt by energy corporates leads to a rise in production capacity and output. Their analysis therefore suggests that quantitative easing policies that enhance extensive capacity investment have been important factors in determining credit risk. Sen Sengupta, Marsh, and Rodziewicz (2017) examine whether there was a change in nature of credit risk for energy corporates in the syndicated loan market in the aftermath of the 2014 oil-price shock. They find that credit conditions tightened following the oil-price shock in mid-2014. On average, the syndicated loan market moved funding towards corporates with improved credit quality. Balcilar, Hammoudeh, Toparli, and Akay (2018) analyze the risk transmission across WTI oil and CDS sectorial oil and oil related indexes as well as financial volatility. Their objective is to discern how major global events affect the transmission of conditional volatilities between the oil and oil related CDS markets. Using the novel Volatility Impulse Response Function, they find time changing conditional volatilities across the WTI price and different oil related CDS portfolios as well as between financial volatility and CDS portfolios. Our paper is related to Balcilar et al. (2018) in that we analyze the relationship between crude oil prices and energy corporate CDSs to specifically address certain global events such as the 2014-2016 crude oil price decline the 2013 taper Tantrum. However rather than concentrating on conditional correlations we analyze the fundamentals of energy CDSs and CDS indexes. In doing this we first apply the PSY methodology for testing for mild explosivity in corporate CDS names and corporate CDS sectorial indexes and associate the time series autoregressive coefficient of CDSs and the proposed fundamentals using the approach by Phillips, Wu and Yu (PWY, 2011) as well as regressions based on time changing autoregressive coefficients. This allows us to establish the extent to which bubble characteristics in crude oil prices affected credit risk and balance sheet measures in single name energy corporates.

The contributions of this paper may be summarized as follows:

First, we show that there is mild explosivity in CDSs in energy corporates and sectorial CDS indexes. Second, episodes of mild explosivity are linked to the time series behaviour of the crude oil prices and the exogenous financial US monetary policy fundamental. This is done following the fundamentals approach by (PWY 2011) and via a series of time series and time series and panel OLS regressions built following the spirit of the migration framework introduced by Phillips and Yu (PY, 2011). Regression results show that mild explosivity in crude oil prices can be linked to autoregressive behaviour of credit risk and the US monetary policy metric. They also demonstrate that on average there is a synchronous relationship between credit risk in the energy sector and crude oil bubbles. Episodes of mild explosivity between US real yield and in CDSs do not occur at synchronous times. Moreover, the exuberance in oil futures prices can also be explained by the bubble components of CDSs confirming an existing dual spillover channel. Third, a set of panel regressions demonstrate that corporate company balance-sheet fundamentals such as capital expenditure (CAPEX) are also affected by the bubble characteristics of credit risk and the US monetary policy. This later finding sheds light to the literature that addresses the influence of monetary policy on the real economy (see de la Horra, Perote and de La Fuente 2021 and references there in). Bernanke and Gertler (1995) claimed that the process of monetary tightening on the cost of borrowing and subsequent real activity are magnified via a deterioration the balance sheet and the fall in the supply of loans. This leads to a decrease in firms´ cash flows and further rises in the cost of capital. The build-up of "financial pressure" under enhanced credit constraints eventually lead to a reduction in investment expenditure as shown in the resultant decline in capital expenditure (CAPEX) ratios. Bernanke and Blinder (1992) showed that a monetary tightening, under a low inflation environment eventually reduces investment spending and aggregate demand, yielding reduced output. This paper provides empirical evidence suggesting that spillovers between credit risk and the price of the collateral asset in the energy sector can be reinforced under tightening monetary conditions via sustained deterioration of the balance sheet.

We choose CDS prices to measure credit risk in the energy sector. We are in this sense consistent with the work of Hammoudeh et al. (2013) who use oil and oil-related CDSs to measure credit risk. In this paper, we concentrate on the relationship between levels in energy CDSs and their fundamental values. We use for this purpose the explosive/bubbles detection methodology recently proposed by Phillips, Shi and Yu (2015a&b: PSYa&b). This constitutes reduced-form framework for testing for departures from an unobservable stochastic factor such as random walk behavior, and departures from fundamental value, in the direction of *mildly explosive process* alternatives. The procedure delivers time series autoregressive coefficients for each variable considered that allow investigating the relationship of CDSs and their fundamental variables.

This paper is organized as follows. Section 2 summarizes de PSY mildly explosive/bubbles testing methodology and specifies the framework used for analyzing price-fundamental relationships. Two approaches are used for this purpose, PWY (2011) method and a time series and panel regression approach based on recursive coefficients. In section 3, we provide a detailed description of our data set. Section 4 reports results for the PSY test implemented to the nine CDS corporates considered and the three energy indexes considered. In section 5, we analyze the price-fundamental approach on the bases of four hypothesis. The fundamentals considered includes two oil price benchmarks, the 10 year US treasury real yields and two balance sheet metrics. We conclude in section 6.

## 2. The PSY mildly explosive framework

We apply the recursive methodology of PSY to date stamp episodes of mild explosivity. The main idea is to use recursive estimations of the Augmented Dickey-Fuller (ADF) unit root test. A recursive regression is run for a fraction $r_1$ and ending at a fraction $r_2$ of the total sample, with window size $r_w = r_2 - r_1$, for the model

$$\Delta x_t = \alpha_{r_1,r_2} + \delta_{r_1,r_2} x_{t-1} + \sum_{i=1}^{k} \psi_{r_1,r_2}^{i} \Delta x_{t-i} + \varepsilon_t, \quad (1)$$

Where *k* is the lag order chosen on sub-samples using the Schwarz Bayesian Information Criterion (BIC), and $\varepsilon_t$ ~ i.i.d. (0, $\sigma^2_{r_1,r_2}$ ). The test is based on the ADF-statistic (*t*-ratio) of the autoregressive coefficient of this regression, which is denoted by $ADF_{r_1}^{r_2}$.

PSY (2015a&b) introduce two statistics, the backward sup ADF (BSADF) statistic and the generalized sup ADF (GSADF) test. They are defined as:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\}. \quad (2)$$

$$GSADF\ (r_0) = \sup_{r_2 \in [r_0, 1]} \{BSADF_{r_2}(r_0)\}, \quad (3)$$

The starting sample of the regression is an initial fraction $r_0$ of the total sample to $r_2$. We follow PSY (2015a) and propose $r_0$ be chosen according to the definition $r_0 = 0.01 + 1.8/\sqrt{T}$, where *T* is the sample size. This methodology defines a particular BSADF statistic. The GSADF statistic is then constructed through repeated implementation of the BSADF procedure for each $r_2 \in [r_0, 1]$. Critical values are obtained by simulation. PSY (2015a&b) provide limiting distribution theory and small sample simulation evidence.

The null test of no mildly explosive periods is based on the GSADF statistic. Date stamping mildly explosive periods is achieved through the BSADF statistic: the origination and termination points of a first mildly explosive period, $r_{1,e}$ and $r_{1,f}$, are estimated, subject to a minimum duration condition, by

$$\hat{r}_{1,e} = \inf_{r_2 \in [r_0,1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\}, \qquad (4)$$

$$\hat{r}_{1,f} = \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T,\, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\}, \qquad (5)$$

Where $scv_{r_2}^{\beta_T}$ is the 100(1 – $\beta_T$ ) % right-sided critical value of the BSADF statistic. The minimum duration condition applied for the test is equal to log (*T*) observations. A mildly explosive period is date stamped if and when the BSADF statistic has been above its critical value for at least $\lfloor T\,\hat{r}_{1,e} \rfloor + \lfloor \log(T) \rfloor$ observations. Conditional on a first mildly explosive period having been found and estimated to have terminated at $\hat{r}_{1,f}$, the procedure is then repeated in search of a second and possibly subsequent periods.

The last step of this procedure requires addressing relevant question from a financial viewpoint, which involves assessing whether the observed temporary deviations from unit root processes in the direction of mild explosivity represent departures from fundamental values. PWY and PY and examine evidence of explosive behaviour in prices and fundamentals by demonstrating that if the fundamental is not explosive the explosive behaviour in prices only arises due through the presence of bubbles. We follow their approach and decompose the value of the CDS premia $P_t$ in period t into its fundamental value $F_t$ and $B_t$ the “bubble” component.

$$P_t = F_t + B_t \qquad (6)$$

In the absence of bubble conditions $P_t = F_t$. Otherwise, equation (6) is satisfied and the bubble component $B_t$ satisfies the condition:

$$E_t(B_{t+1}) = (1+r)B_t \qquad (7)$$

Under bubble conditions CDS premia will reflect the bubble inherent in $B_t$. The approach followed in this framework will conclude that there is bubble behaviour if there is mild explosivity which is not captured by the fundamental.

In order to test whether the observed mild explosivity arises from fundamental forces we use the following two approaches:

We first test for mild explosivity in the fundamental applying the PSY test on the relevant economic and financial series. The second approach constitutes a series of time series and panel regressions based on the *recursive autoregressive coefficients* which are allowed to be time dependent in a way that it captures structural changes in the statistic arising from exuberance and collapse. The objective is to explain potential links between the changing autoregressive characteristics between energy CDSs and the corresponding fundamentals. The series of regressions estimated for this purpose use methods similar to the interactive model suggested in PY for testing the bubble migration model. Our fundamental based approach differs from the migration hypothesis of PY in that it focuses on a whole sample link between recursive autoregressive coefficients rather than considering the period that covers the collapse of the bubble in one series with the emergence of exuberance in another financial series.

Because the bubble migration hypothesis is designed for the single bubble case it is not clear how to proceed under the existence of multiple bubbles. This is because the literature has not delivered a proper test that looks at long term co-movement of co-explosive processes in a context where there are multiple bubbles and periods of spikes in the series not fulfilling the minimum bubble condition. In the absence of a rigorous framework we do a series of price- fundamental iterative regressions of the following form:

$$\delta_{P,t} = \varphi_0 + \varphi_1 \delta_{F,t} + \varepsilon_t, \qquad (8)$$

$$\delta_{F,t} = \varphi_0 + \varphi_1 \delta_{p,t} + e_t, \qquad (9)$$

Where $\delta_{P,t}$ is the time dependent recursive estimated autoregressive parameter of the CDS series and $\delta_{F,t}$, is the corresponding recursive autoregresive for the fundamental series, $\varepsilon_t$ and $e_t$ are stationary regression errors. Recent literature based on the PSY approach that embeds the analysis of fundamentals and speculation into the testing procedure includes FFMP, Shi (2017), Engsted, Huiid and Pedersen (2016), Figuerola-Ferretti Gilbert and McCrorie (2014) and Figuerola-Ferretti and McCrorie (2016). The fundamental testing approach in all cases requires applying the PSY testing procedure to the fundamental time series. Figuerola-Ferretti Gilbert and McCrorie (2014) perform an additional approach on the fundamental in which the bubble length si regressed against stock consumption ratios using a Tobit regression for the non-ferrous metal case. Bellón and Figuerola Ferretti (2021) have recently followed the logistic approach applied by Bouri et al. (2021) for the analysis of Ethereum bubbles. In this paper we introduce a price- fundamental association testing procedure by means of time series and panel regressions to establish a direct link between bubbles in CDS premia and their fundamentals. This allows us to use all the information inherent in time changing autoregressive coefficients under defined statistical limit theory (see PY).

The analysis of credit risk in the context of mildly explosive behavior has been addressed in the housing price literature by Pavlidis et al. (2018). In their paper, they use the PSY methodology to provide new evidence underlying the role of interest rates and policy uncertainty factors in explaining mildly explosive dynamics in housing prices. In a related paper, Shi (2017) uses macroeconomic variables including real rates to control for fundamentals in the housing sector.

### 3. Data

We have collected weekly single 5-year CDS spread data for twelve energy corporates selected on the basis of market capitalization and data availability. Table 1A in the appendix displays the list of the twenty companies ranked according to market capitalization. The use of CDS spreads for single names can be problematic due to liquidity reasons. We have selected for this purpose eleven for which there is a continuous set of CDS data. In order to guarantee the reliability of our sample, we follow Diaz and Serrano (2011) in requiring that the percentage of missing values does not exceed 15% of the total sample. Details on companies selected given the second filter of data reliability are provided in Table 1B. This reports the samples used in the first part of the analysis for the following twelve companies: Royal Dutch Shell Plc (Shell), Chevron Corporation (Chevron), Total SA (Total), BP p.l.c (BP), ConocoPhillips (Conoco) , Eni S.p.A (Eni), Valero Energy Corporation (Valero), Marathon Petroleum Corporation (Marathon), Kinder Morgan Inc Class (Kinder), Pioneer Natural Resources (Pioneer), and Repsol SA (Repsol). Exxon Mobil Corporation, Anadarko Petroleum Corporation, and Williams Companies Inc., were dropped from the analysis due to the lack of reliable CDS data across the whole sample.[1] We failed to find 5 year CDS data for ONEOK, Inc and Concho Resources Inc.

[1] The number of missing observations was beyond 15.%

Application of the PSY methodology requires simulation of critical values under the null random walk hypothesis. Note that that due to data availability there are three sample sets used in the analysis. The largest sample runs from January 2003 to December 2019 and uses 886 weekly observations. Later initial sample dates are used for Shell, Chevron and Pioneer. Sample dates for Shell, Chevron and Pioneer range from January 2010 to December 2019 delivering 522 observations.[2]

We analyse three Energy CDS sectorial indexes covering the European, American and Asian corporates respectively for a sample of 469 observations ranging from January 2011 to December 2019. These are the America Energy IG 5 year CDS index, Europe Energy IG 5 year CDS index and Asian (ex Japan) energy 5Y CDS index. Details regarding composition of these indexes are provided in tables 1C, 1D and 1E Reported figures show that the three indexes are equally weighted and that while the American benchmark is made out 30 single name CDSs, the European and Asian indexes contain seven single company CDSs.[3] As discussed by Hammoudeh et al. (2013) credit spreads quoted by sectorial indexes gauge the default risk exposure of the firms that comprise the sector portfolios. CDS sectorial indexes exhibit higher trading liquidity and therefore are expected to be a more accurate and diversified measure of credit risk.

Index and single CDS spread data are collected from Bloomberg. We also use weekly Energy Information Administration (EIA) data for front month futures prices of

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[2] Although data for Shell was available from 2004 there is discontinuity in the data until 2007. We thus decide to start the sample from the same date as Chevron and Pioneer. Missing values are replaced by the previous observation to guarantee continuity of the data across time, which is an important requirement for the correct date stamping and bubble detection under the PSY methodology.

[3] We analyze all components of the European benchmark index apart from one (Technip SA) while only six components of the American benchmark index (Chevron, Conoco, Valero, Kinder Pioneer). Although we do not cover any single CDS component of the Asian benchmark, we believe it is interesting to analyze credit risk for the Asian area at an aggregate level.

West Texas Intermediate (WTI) and Bloomberg data for front month Brent blend.[4] Our fundamental data includes the Bloomberg 10-year real US Treasury yields. Real yields are calculated as the Treasury yields minus the break-even rate for the corresponding maturity for the January 2003 to the December 2019 period. Additionally, we have quaterly data for total debt, EBITDA and CAPEX for each energy corporate analyzed. The data source for the latter is Factset for the 2003-2019 period.

Fig 1A represents the weekly time series plot of spot prices for the two international crude oil benchmarks (Brent and WTI) crude oil spot prices as well as the 10yr real US bond yield for the Jan 2003 December 2019 period. The US Treasury 10 year Index measures the difference between the ten-year US yield and the 10-year breakeven. The breakeven inflation rate represents inflation derived from 10-Year Treasury Constant Maturity Securities and 10-Year Treasury Inflation-Indexed Constant Maturity Securities. The later metric measures what market participants expect inflation to be in the next 10 years on average. [5] By using real Treasury yields, we capture the extent to which the Fed overreaction to the perceived risk of inflation leads to increased credit risk in financial markets.[6]

The time series plot in Fig 1A reflects three main problematic periods: 2007-2009, 2010-2012, and 2014-2016. The first period relates to the GFC. We can see that

[4] Recent applications of PSY methodologies in crude oil spot prices include Fantazzini (2016) and Sharma and Escobari (2018).

[5] See definition by the Federal Reserve of St. Louis.

[6] According to Bloomberg news on the 22d of May of 2013 the Federal Reserve Chairman Ben Bernanke hinted a reduction in stimulus with the consequence that there was a "sell-off that erased years of stimulus-led gains in currencies and stocks, spurring defaults globally." (article available at https://www.bloomberg.com/news/articles/2018-05-22/not-a-happy-anniversary-em-s-taper-tantrum-began-5-years-ago).

the US real Treasury yield Index moves from 2.71% in July 2007 to 0.97% in March 2008 while crude oil prices increase from $74 in July 2007 to reach a peak of around $147 in July 2008. Crude oil prices collapsed in the mid-summer to reach $47 in November 2008 while the real yield reaches a maximum of 3.06%. We thus see a strong negative co-movement between the 10-year real yield and (Brent and WTI) crude oil spot prices during this episode. Over the second 2010-2012 period, markets are subject to expansionary monetary policies while being exposed to the propagation of the European sovereign debt crises. In this new phase, crude oil prices rise abruptly to trade above the $100 level for a period of three years or so,[7] and real yields decrease substantially reaching minimum levels in December 2012. The third 2014-2016 episode which is central to the results in this paper starts with the crude oil price slump in the summer of 2014 which drove prices to the 45$ level in December 2014. The process continues until January 2016 when crude oil prices reach floor levels. We shall link this later episode to the tapering announcement in May 2013 which led to sharp increases in the 10-year real yield, which moves from -071 in April 2013 to 0.67% in July 2013.

In this paper, we investigate the extent to which he above analysis is consistent with the mechanism underlined by Bernanke and Gertler (1995). The Federal Reserve decision to taper in September 2013 may have been a factor that influenced the 2014 collapse of crude oil prices in a context of slowing growth in the GDP of China and the Greek default in 2015. Indeed there was a second explosion of financial market volatility in October 2014, when the Fed's intentions to raise interest rates in 2015 became clearer.[8]

[7] Note that over the 2010-2014 period the spread between WTI and Brent prices increases substantially.

[8] *Irwin, Neil (August 24, 2015). "Why the Stock Market Is So Turbulent". The New York Times.*

This situation contributed to the deterioration of balance sheets in energy corporates which suffered an average increase of 40% in debt equity ratios in the last quarter of 2014 and the building up of credit risk. In what follows, we comment on the time series evolution of CDSs.

Figs 1B and 1C depict the behavior of the twelve analyzed CDS energy corporates. The former illustrates CDS spreads for the 2010-2019 period and the later shows corporate CDS spreads for the 2002-2019 period. We can see from fig 1C that CDSs experience sharp increases during the GFC especially towards the last quarter of 2008 and early 2009. Both figs 1B and 1C show that there are significant spikes during the European sovereign debt crisis. In the early stages, we see abrupt increases in 2010 when Greece had announced that it required a bailout program. We also see important increases in March 2011 and in May 2011[9] around the time that the S&P credit rating agency had announced a negative outlook on the AAA rating of the US sovereign debt. [10]. CDSs spike again in March May 2012 at the point that Spain and Cyprus requested official funding. [11] After this episode CDS spreads, remain trading at around the 100 bp level for a period of two years.

The third period of sharp increases in credit risk starts in December 2014, just around the collapse of crude oil prices and after the third run of Quantitative Easing is completed by the Fed. We see a more pronounced peak in CDS spreads in December 2015 when the Fed starts raising interest rates. Note that over the same period crude

[9] In May 2011 the bailout program for Portugal was announced after the official assistance was launched for Greece in May 2012 and for Ireland in November 2010.
[10] The downgrade to AA+ took place on August 2011 after the United States Congress voted to raise the debt ceiling of the federal government.
[11] For a detailed discussion on the European Debt crises see Lane (2012).

oil futures prices were reaching floor levels and that an even more abrupt period of rising CDS spreads is observed in February 2016. CDS spreads were affected in Europe as well as the US.

Fig 1D illustrates the time series evolution of the three CDS energy indexes analyzed: a) Europe Energy IG 5yr CDS, b) America Energy IG 5y CDS, c) Asia (Ex-Japan) Energy 5y CDS for the 2011-2019 period. Although no Asian individual CDS names are analyzed we look at the Asian Ex-Japan CDS index to test whether departures from martingale behavior in credit risk indexes goes beyond the US and Europe. We see that both the American, European and Asian benchmarks peak in September 2011 reaching levels of 181, 193 and 374, respectively suggesting that single CDS names in the three continents where affected by the European Sovereign Debt crises. [12] CDS indexes remained calmed until 2014 when the American and European benchmarks moved from 54bp and 67bp respectively in mid-August to 84bp and 169 bp in December 2014. In synchrony with the behavior of the single name CDSs, we see a more pronounced episode of spread swings is seen in February 2016 when the American, European and Asian CDS index benchmarks reach 217, 493 and 315 bps respectively to loose half of their value by April 2016. Our preliminary analysis shows that (as expected) European and American corporates were more affected by the US monetary policy announcements and the 2014 crude oil price shock than their Asian counterpart. Fig 1D

[12] We find to reason why there might have been contagion to the Asian (ex-Japan credit markets.) First GDP growth in Asia ex-Japan steadily decelerated after the first quarter of 2010. Second, Debt markets in Asia were vulnerable due to the high percentage of foreign ownership. There is evidence that suggests that foreign buyers pulled out from the Asian fixed income market from August to September 2011.

also shows that more recent increases in index levels are seen in January 2019 following the consecutive increases in the Fed rate in 2018 under a rise of economic uncertainty.[13]

In what follows we formally investigate whether the observed CDS spread swings can be associated with departures from martingale behavior. We do this for individual CDS names as well as for CDS indexes. We also analyze whether the three periods of abrupt spread swings can be associated with the 2008 and 2014 crude oil extreme price movements, with the 2013 tapering announcement and to a deterioration of balance sheet leverage related measures.

## 4. Econometric analysis: PSY test results

### 4.1 Results for individual CDS premia on energy corporates

We conduct the first two stages of the PSY test using CDS spreads for the twelve corporates underlined in table 1B. This allows documenting any detected departures from normal martingale trend behavior in the direction of mildly explosive alternatives. A summary of our results is provided in table 2A where we report periods of mild explosivity found for the 12 corporates and three benchmark CDS indexes analyzed on the basis of GSADF and BSADF test results. We denote periods of mild explosivity that are only significant at the 10% level with the superscript (*). Dates where the BSADF statistic crosses the 5% critical value line for a number of weeks that is above two weeks but below the minimum bubble condition are noted by the superscript ($^{MB}$).

[13] The Fed began raising interest rates. In total, the Fed raised rates nine times between 2015 and 2018, by 0.25 percentage points each time. In light of increased economic uncertainty, the Fed then reduced interest rates by 0.25 percentage points in a series of steps beginning in July 2019. (see https://www.everycrsreport.com/reports/RL30354.html)

Overall, all single CDS names for which we have data from 2003, exhibit departures from random walk behavior during the GFC. We report results for mild explosivity during the GFC in two sub-periods. There is one sub-period starting in the summer of 2007 and lasting until September 2008. The second sub-period begins after the collapse of Lehman Brothers. Table 3 shows that during the first GFC sub-period we find mild explosivity in seven corporates. Interestingly most mildly explosive episodes end around the time that crude oil prices become exuberant (April 2008). The second GFC sub-period in table 3 ranges from October 2008 to June 2009. It therefore represents the period after the crude oil price collapse and the Lehman´s debacle. We report mild explosivity for five corporates over that period.

During the 2010-2012 period, there are departures from martingale behavior reported at the significance 5% level for two corporates and at the 10% for three corporates. Other evidence of mild explosivity with the minimum bubble condition not being satisfied is found for three companies. This paper focuses on the third episode of significant departures from martingale behavior, which is detected over the 2015-2016 period (for single name CDS spreads) and over the 2014 as well as 2015-2016 for the European and American sectorial CDS indexes considered. We report mild explosivity at the 5% level for five single name CDS three of which (Conoco Phillips, Marathon Petroleum and Kinder Morgan are American). The minimum bubble condition is not satisfied in CDS spikes observed in four CDS corporates.

A last episode is date stamped in energy corporates in 2018, which delivers exuberance for 4 individual corporate CDSs. This takes place between the two consecutive raises in the Federal rate that took place in the last quarter of 2018. The

Federal Open Market Committee (FOMC) decided to raise the Federal funds rate on the 26th of September 2018 and on the 19th of December 2018. [14]

Details on econometric results for single name CDSs are reported in tables and top panels of tables 4A-4C (date stamping on the basis of the BSADF statistic).[15]

We assess the robustness of our results to the existence of non-stationary volatility by applying the bootstrapped critical vales introduced by Harvey (2016). As discussed in Figuerola-Ferretti et al. (2016), this procedure controls for the existence of heteroskedastic errors by replicating the pattern of volatility that is present in the original innovations.

The PSY methodology under the wild bootstrapped method is first applied for each single CDS name. Date stamping under the wild bootstrapped methodology is reported under the lower panels of tables 4A to 4C. The overall evidence shows that mildly explosive periods remain robust for all single CDS name apart from BP, which exhibits no statistically significant departures from martingale behavior under wild bootstrap, as the minimum bubble condition is no longer satisfied. Royal Shell, Pioneer and Repsol exhibit mild explosivity only significant at the 10% level in contrast to the 5% level reported under the standard application. In all cases however, periods of mild explosivity are shorter under the wild bootstrapped methodology. Figs 2A to 2L exhibit the time series evolution of BSADF statistics and 5% critical value line for the standard critical value case and the more stringent wild bootstrapped critical value method.

[14] The consecutive FED rate increases are provided in the following link https://en.wikipedia.org/wiki/Federal_funds_rate#Historical_rates

[15] Results of GSADF statistics are not reported here for space saving purposes. They can be provided upon request. These are all significant for the series considered.

### 4.2. Results of CDS sectorial energy indexes

We report PSY test results for the three benchmark sectorial 5-year CDS indexes in table 4D which shows date stamping on the basis of BSADF statistic. Data for these indexes is only available from July 2011, which means that we are restricted to date stamp mildly explosive periods from that point in time. The initial sample $r_0$ is adjusted accordingly. Results from the application of the PSY methodology to the CDS sectorial indexes (under the standard and wild bootstrapped critical values) are reported in table 4D as well as figs 3A-3C, which exhibits the time series of the BSADF sequence under standard critical values as well as the bootstrapped case.

Results are consistent with those reported in the previous section. We find that higher degree of exuberance in the American index which exhibits two episodes of mild explosivity. There is an initial two-week spike on the 17th of October 2014 to be followed by a ten-week episode of mild explosivity which ranges from the 5th of December 2014 to the end of January 2015. We shall see within the next section that this is episode synchronous to the 2014 period of mild explosivity date stamped for WTI and Brent futures prices. This period of mild explosivity is also robust to the existence of non-homoscedastic errors as reported in panel b of table 4D as well as in fig 3A. The next statistically significant rise is a 12 week episode date stamped from mid- December 2015 to March 2016 which is also dated stamped in panel B. For the European benchmark we find a shorter 8 week episode (from January to March 2016) of mild explosivity that does not fulfill the minimum bubble condition when we allow for heteroskedastic errors. The Asian CDS index shows exuberance from August 2015 to October 2015 possibly reflecting the Asian stock market collapse and lower GDP growth in China as well as the consequences of the crude oil price collapse.[16] A later episode of mild explosivity not fulfilling the minimum bubble condition is date stamped in February 2015 for the Asian benchmark.

As was the case for 4 of the individual CDS we see a last episode of mild explosivity in the American CDS index from November 2018 up to Mid-January 2019 following the two consecutive increases in the Fed´s rate. [17] However, this is not longer dated stamped under the more stringent wild bootstrapped critical value approach.

## 5. The study of fundamentals

In what follows, we analyze the fundamentals that have affected credit risk in energy corporates during the period analyzed. The main question that we address is the extent to which credit risk is determined by variables within the energy sector as well as wider exogenous influences. We consider for this purpose the time series properties of the debt collateral the crude oil price and other financial variables.

In what follows we address the role of fundamentals in two stages. We first test for mild explosivity by analyzing evolution of BSADF statistics of the corresponding fundamentals. We then run a series of (time series and panel) regressions to relate bubble components of CDS spreads and the energy related and exogenous fundamentals.

### 5.1. The real Treasury yield

[16] This episode is only significant at the 10% level under the wild bootstrapped critical values

[17] In the European CDS index case this episode des not fulfill the minimum bubble condition.

Table 4F reports the periods of mild explosivity of the US ten year real yield as shown by the BSADF statistic.[18] The time series plot of BSADF statistics and the critical value line is illustrated in fig 4B. A close inspection to fig 4b shows that there are three weeks in which the BSADF statistic is above the 5% in June-July 2013 under the standard PSY critical value case. There is another (two-week) spike that takes place during the European sovereign debt crises. While the evidence provided does not suffice to declare mild explosivity there is a suggestion that worsening credit conditions arising from the taper tantrum lead to an abrupt spike in US Treasury real yields. We investigate the extent to which the (short) mildly explosive components seen in the US real treasury yields are related to credit risk in section 6.

### 5.2 Crude oil prices

We perform the PSY test on the two international oil futures price benchmarks. The front month ICE brent futures as well as the WTI NYMEX front month futures. FFMP show empirically that for the two crude oil price benchmarks the use of spot prices and futures prices is inconsequential as long as the focus of analysis is on the detection and date stamping of mildly explosive periods. Figures 4B and 4C exhibit the BSADF sequences for the two benchmark futures price series at the 5% significance level. As shown in the top panels of table 4G, we find that under the WTI nominal futures price series there is positive mildly explosive episode dated from mid-May and mid-July 2008 (when nominal prices are rising) and a negative mildly explosive episode dated between October 2014 and mid-February 2015 (when nominal prices are falling). This consistent with the results reported by FFMP who report a first bubble in crude oil front prices in

[18] GSADF statistics are not reported in this section for space saving purposes. They can be provided upon request.

the second and third quarters of 2008 and a second episode beginning in late 2014 and lasting two months or more during the post June 2014 to February 2016 crude oil price decline.[19] FFMP underline the importance of the OPEC late November in which the group decides to maintain its production ceiling rather agreeing on production cuts as seen in its usual policy. WTI and brent front month crude oil bubbles are date stamped before this meeting under the standard PSY critical values. [20] We analyze the robustness of this result by considering the more stringent wild bootstrapped critical values and we see that the 2014 bubble is dated from December 2014 to February-March 2016. This evidence therefore suggests that the date-stamping of the origination of the 2014 episode using the standard PSY critical values was not robust to the existence of non-stationary volatility.

As it is discussed earlier in the paper, the 2008 bubble reported for front futures crude oil prices takes place before the first period of exuberance date stamped for single name CDS spreads. Prior to May 2008 and during the early stages of the GFC seven single name CDSs exhibited departures from martingale behavior. Table 4H shows that the nominal Brent series date a period of mild explosivity between January 2011 and May 2011 during the middle phase of the European Sovereign debt crises. [21] This period of mild explosivity dated stamped in Brent prices precedes the later episodes reflected in single CDS prices of Kinder, Conoco and Stat oil which reflect mild explosivity in the

[19] Note that the 2008 bubble for spot brent prices does not satisfy the minimum bubble condition to declare a bubble at the 5% or 10% level as reported in FFMP. The 5% significance level is just missed by one observation given the minimum bubble condition of 7 weeks.
[20] Note that similar results were obtained for spot prices by Fantazzini (2016) and by FFMP for brent spot prices.
[21] Note that a similar episode was detected in FFMP for brent nominal prices but the minimum bubble condition was missed by one observation.

autumn of 2011. Statistically significant departures from martingale behavior are also exhibited in 2012 in the CDS of Repsol.

A central result in this paper is that the 2014 bubble dated for the WTI and brent under the bootstrapped critical futures prices is synchronous with the first period mild explosivity dated stamped in the American CDS index sectorial benchmark, which represents a larger basket of CDSs than its European and Asian counterpart.

The dual relationship between CDSs and the debt collateral changes in the aftermath of 2014 where sectorial energy CDS indexes as well as in individual CDS names) exhibit periods of time explosivity around the time in which crude oil prices reach minimum values in January 2016. Mild explosivity is reported for the three energy CDS indexes considered as well as for the case of Chevron (10% level), Royal Shell, Repsol, Conoco and Marathon. We find spikes that fail to satisfy the minimum bubble condition in, Total, BP, Statoil.

As opposed to the 2014 episode, the bubbles shown in CDS indexes towards the end of 2015 and beginning of 2016 are not reflected in negative mild explosivity of crude oil futures prices. This suggest that there may be other wider factors causing the bubbles seen in CDS sectorial indexes. We explore for this purpose in greaterdetail the relationship between CDS premia and CDS fundamentals.

**5. Regression analysis**

We formally analyze the relationship between time dependent autoregressive parameters in CDS spreads and their different fundamentals by running a series of time series regressions as specified in (8). The methods applied are related to the migration test of PY where the identification of one single bubble in each of the time series considered is required. This paper focuses in the multiple bubble phenomena using the PSY methodology. We apply a regression approach that exploits the information inherent in autoregressive coefficients of prices and fundamentals. This allows us to analyze weather there is association of bubble characteristics in CDSs and their fundamental series in a context of multiple bubbles or periods of mild explosivity not fulfilling the minimum bubble condition as is the case documented for the US real 10 year bond yield. The following hypotheses are tested for this purpose:

*Hypothesis A: Because crude oil is the debt collateral of energy corporates, lower oil prices reduce profitability of oil producers as well as increasing the debt financing costs and the default probability.* We test this hypothesis by estimating a regression where the time dependent autoregressive parameter of crude oil futures is the explanatory variable and the recursive autoregressive estimate of CDSs is the explained variable.

*Hypothesis B: An increase in interest payments under a falling value of the collateral delays the process of production cuts that is to be followed to balance the markets. Firms are forced under these circumstances to sell oil at prices bellow break even levels.* Under this hypothesis, we expect that the bubble component of the real US10 to be related to the bubble component of CDSs. We should also find that credit risk and the oil price interact in a dual channel. Bubble components in credit risk as measured by CDSs and

CDS indexes are expected to affect crude oil futures prices and crude oil prices are expected to affect CDSs and CDS indexes.

*Hypothesis C*: *the process of monetary tightening on the value of the collateral and the cost of borrowing are magnified by an increase in credit risk and a deterioration of the balance sheet. This leads to a decrease in firm´s cashflow which further rises the cost of capital and a decline on capital expenditure*. This hypothesis is tested by analyzing the effects of bubble characteristics in credit risk and the 10 year US real yield on balance sheet fundamentals.

We consider the October 2011- December 2019 weekly sample so that autoregressive coefficients for all individual corporates as well as individual CDS indexes can be included.

**5.1. Time series Regressions**

In this section we measure credit risk by focusing on the European and American CDS indexes.

Table 5 reports results from estimating by OLS equation 8a. Newey West standard errors are reported for robustness purposes. The first and second columns in panel A report results from regressing autoregressive parameters in the American CDS index with WTI US crude oil futures (column 1) and the brent crude oil futures respectively (column 2). Reported figures show that the autoregressive coefficient for the American CDS index is positively and statistically significantly linked to the time varying autoregressive coefficients of crude oil WTI as well as to the brent futures.

The positive sign reflects the synchronous behavior between the bubble series. This is consistent with table **4D** which shows that there is overlapping in the date stamping of the 2014 crude oil price bubble with that reported for the American CDS index. The negative episode of mild explosivity found towards the end of 2014 for oil futures prices shock is associated with an increase in the level of credit risk and bubble behavior resulting from explosive widening of the CDS spreads.

Similar results are reported for European CDS index in the second panel. We therefore offer some evidence supporting hypothesis A for the American and European CDSs indexes.

Reported figures in panels I and II of table 5 show that there is a (marginally) statistically significant link between the recursive evolution in autoregressive coefficients of the US 10year real yield and the corresponding metric for the American and European CDS indexes. The reported OLS slope coefficients are negative suggesting that bubble behaviour is non-synchronous between the US ten year yield and the CDS indexes. We therefore offer some evidence suggesting that Hypotheses A and B is supported for the European and American case. Estimated coefficients presented in the fourth columns of panels I and II show that there is a positive and significant relationship between the bubble components in CDS indexes across European and American areas.

We interpret the negative and significant coefficient (see column 3 in panels I and II of table 5) indicating that on average periods of (positive or negative) mild explosivity (where the autoregressive coefficient $\Phi$ takes a positive value) are nonsynchronous between the two variables considered. This is the case seen for the relationship between bubble components between the US 10 year real yield and credit risk as measured by the European and American index CDSs. The negative coefficient may be capturing the fact that the short period of mild explosivity dated over 2013 due to the tapering announcement is non-synchronous with the period of exuberance observed in 2015 for the European index benchmark and 2014 and 2015 for the American Index benchmark.

**5.2 Panel OLS Regressions:**

**5.2.1 CDS sectorial indexes**

We jointly consider the relationship between individual CDSs or sectorial CDS indexes and different fundamentals by applying a panel-based strategy. Regressions are designed to measure the price-fundamental spillover process in a context of multiple bubbles or spikes not fulfilling the minimum bubble condition. For each week *t* we estimate the following cross-sectional regression:

$$\emptyset_{CDS,i,t} = \alpha_{1,i} + \beta_{1,i}\emptyset_{brent,t} + \beta_{2i}\emptyset_{US10,t} + \varepsilon_{i,t}, \quad (9)$$

$$\emptyset_{brent,t} = \alpha_{2,i} + \omega_{1,i}\emptyset_{cds,i,t} + \omega_{2i}\emptyset_{US10,t} + \varepsilon_{i,t}, \quad (10)$$

$$\emptyset_{US10,i,t} = \alpha_{3,i} + \theta_{1,i}\emptyset_{brent,t} + \theta_{2i}\emptyset_{CDS,t} + \varepsilon_{i,t}, \quad (11)$$

Where $\beta_{k,t}$ $\omega_{k,t}$ $\theta_{k,t}$ constitute the coefficient of the variable *k* in period t, $\varepsilon_{I,t}$ is the regression residual. Changes in the time series variable $\emptyset_{US10,i,t}$ are expected to have a common effect on each CDS index. Its impact may be captured by equation (9) or indirectly through the specification of crude oil futures price equation (10). Changes in bubble characteristics of the oil futures variable will have a common effect on the time series evolution of the autoregressive parameters of the CDS energy indexes considered as represented in equation (9). In this framework two autoregressive variables are included to capture changes in the dependent variable that varies over time as well as crossectionally via entity effects and time effects.

Results from estimating equation (9, 10 and 11) are reported in table 6. In order to keep simplicity of exposition we concentrate in this section on the crude oil brent futures.[22] Column 1 considers autoregressive parameter data for the three individual CDSs indexes. Columns 2 and 3 report results for the bubble components oil brent futures and the US 10 year real yield (US10).

Overall, the findings indicate that there is a statistically significant link between the time changing autoregressive coefficient of the three-energy index CDSs and the corresponding time series for the crude oil futures fundamental (see columns I and 2 of table 6). There is also a statistically significant link between the bubble components of the crude oil brent future fundamental as well as the monetary policy fundamental (see columns 2 and 3 of table 6). The effect of the bubble component in the US 10 real rate on the CDS index bubble characteristics is captured indirectly through the brent futures. In this sense short periods of mild explosivity documented for US 10 year real yields contributes to lower crude oil prices and the loss of value of the CDS collateral. While episodes of mild explosivity are synchronous for the oil brent futures and for the CDS indexes explosive behavior is not synchronous when considering the US 10 year real yield and the crude oil fundamental.

We can therefore confirm that results reported in columns two and three in table 6 offer evidence in favor of hypothesis A (negative mild explosivity in crude oil prices significantly affects credit risks). The also support hypothesis B (the short periods of mild

[22] Results are robust to the application of WTI futures and can be provided upon request.

explosivity seen in the US 10 yr real rate affect the behaviour of CDS indexes through a decreasing explosive trend in the value of the collateral). Estimated coefficients reported in column three offer evidence confirming a dual relationship between oil futures prices and US 10 year real yields.

**5.2.2 Individual company CDSs and company corporate fundamentals:**

In what follows we proceed hypothesis C and shed light to the channel theory of Bernanke and Gentler (1995). This requires consideration of autoregressive components of the 12 company CDSs within a two stage panel regression with fixed and time effects. For each quarter, we estimate the following cross section:

$$\emptyset_{CDS,i,t} = \alpha_i + \beta_{1,i}\emptyset_{brent,t} + \beta_{2i}\emptyset_{US10,t} + \varepsilon_{i,t} \qquad (12)$$

$$RAT_{i,t} = \gamma_{0,t} \quad + \gamma_{1i,t}\widehat{\emptyset}_{CDS,i,t} + \gamma_{2i,t}\hat{\beta}_{2,t} + v_{i,t}, \qquad (13)$$

Where $\gamma_{1,i,t}$ constitutes the coefficient of the variable $\emptyset_{CDS,i,t}$ in quarter *t* and for each corporate CDS autoregresive variable *i*. $\beta_{2,t}$ is US 10 bubble factor, which is estimated under equation (12) for 12 week rolling samples and averaged over quarters. $\gamma_{2i,t}$ is the corresponding coefficient estimate for the US 10 year autoregressive factor. The panel OLS python routine is used for this purpose.

Panels I and II, of table 7 report estimated $\gamma_1$ and $\gamma_2$ coefficients for the financial ratios $Rat_{t,i}$ considered which comprise the firm assets and liabilities. These are defined as: $CAPEX/DEBT_{i,t}$, and $DEBT/EBITDA_{i,t}$ respectively.

Reported results show a synchronous effect of the US 10 year real yield factor on the capex/debt ratio and a negative (non-synchronous) coefficient corresponding to the company CDS bubble components. This captures the process by which the rise in US 10 year real rates (in a context of rapidly increasing CAPEX) eventually leads to explosive credit risk that deteriorates CAPEX/DEBT ratios as reflected in the negative and significant coefficient reported for the individual CDS bubble component. Given that the unexpected changes in monetary policy such as the 2013 taper tantrum announcement triggered volatility in the market, results are also consistent with the work of De la Horta et al. (2021) who highlight how monetary shocks under high uncertainty environment discourage immediate capital investment. The effect of the US 10 year real rate on the DEBT/EBITDA ratio is also positive and statistically significant signaling that monetary tightening deteriorates the balance sheet by delivering higher DEBT/EBITDA ratios. The individual CDS bubble component does not have a significant effect on DEBT/EBITDA.

Our panel results therefore shed some light on to hypothesis C, which states how the process of monetary tightening on the cost of borrowing are magnified via a deterioration of the balance sheet.

## 6. Conclusions

This paper provides a new dimension to the relationship between credit risk in the energy sector and its fundamentals over the last two decades. We consider for this purpose the crude oil natural fundamental and other exogenous financial variables. We measure credit risk in energy corporations using CDS spreads and assess whether credit risk in energy companies exhibited significant departures from random walk behavior using the PSY methodology. We find that there is mild explosivity in individual corporate

CDS spreads as well as three energy CDS sectorial indexes. We analyze the causes of statistically significant increases in credit risk by looking at the crude oil price the US 10 year real yield as well as a number of leverage and capital investment measures. The objective is to offer a new empirical evidence explaining the 2014 crude oil price shock shedding light to the effects of monetary tightening as well as worsening credit risk and balance sheet conditions in energy corporates. Our contributions are summarized as follows:

1. Using the multiple bubble methodology proposed by PSY we detect two robust mildly explosive periods in CDS spreads: one predominant statistically significant rise beyond what is consistent with random walk behavior during the GFC and another important mildly explosive period during and in the aftermath of the 2014 crude oil price collapse. The 2015-2016 episode coincides with point in which crude oil prices reach floor levels. Another less significant episode is documented for fewer corporates around the European sovereign debt crises and the 2011 downgrade of the US debt. We also look at European and American CDS sectorial energy indexes date stamp important departures from martingale behavior starting in December 2014 and in December 2015.
2. We analyze the time series properties of crude oil, the tangible fundamental of CDS energy corporates. Consistent with FFMP we find mild explosivity in both Brent and WTI nominal and real spot prices between mid-May and mid-July 2008 in the midpoint of the GFC. Another statistically significant fall is seen in oil prices starting in late November or early December 2014 lasting for a period of eight weeks or so. We also report mild explosivity in the context of increasing prices between March and May 2011 in the crude oil Brent benchmark; however, this

later episode is not robust. Mild explosivity seen in CDS spreads can therefore be tied to the value of the natural fundamental, the crude oil price. Moreover, the statistically significant rises in the spread of CDS US sectorial indexes date-stamped 2014, is exactly synchronous to those detected for the crude oil nominal and real benchmarks, showing that the American CDS portfolios reflects more accurately the value of the fundamental than single name CDSs.

3. We apply a new approach to test the price fundamental relationship based on time series and OLS regressions of recursive OLS regression coefficients. This allows us to capture the extent to which there is a significant relationship between credit risk and its fundamentals in the context of multiple bubbles or short periods of mild explosivity.
4. Our results show that mild explosivity of CDSs is significantly linked to the crude oil fundamental. Bubble characteristics in this context are on average concurrent. A statistically significant relationship is also found between recursive ADF of credit risk and the US 10 year real yield.
5. A set of panel and time series regressions demonstrate that there is a dual relationship between bubble components of CDSs and crude oil prices as well as a non-synchronous relation between credit risk and crude oil prices with US 10 year real yields. We provide evidence showing that there is a link between US real yields, credit risk the CAPEX/DEBT ratios. The bubble component of US 10 year rates do also have a positive and significant effect on DEBT/EBITDA ratios.
6. We are therefore able to provide evidence supporting the credit channel theory. Of Bernanke and Blinder (1992) and Bernanke and Gatler (1995) as they illustrate how a falling value of the debt collateral combined with a tightening of monetary

policy under low inflation environments, lead to a deterioration of credit risk and leverage measures underlying energy corporates, eventually affecting long term investment. They also illustrate how the 2014 episode exemplifies the dual interaction between the price of the crude oil debt collateral and the firm´s credit constraints, which enhances the transmission of shocks in the economy.

7. Our results are highly relevant in a context in which inflationary pressures under the port COVID recovery are pushing Central Banks to reconsider the timing of expansionary policy. They are also important for the future valuation of fossil fuel reserves which are highly conditioned by the climate policy actions that aim to achieve the 2050 net zero emissions goal (see Atanasova and Schwartz 2021).

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## Appendix 1:

## Tables

**Table 1A: Energy Corporates Ranked by Market Cap (Dec 2017)**

| Company Symbol | Company Name | MktVal Co USD |
|---|---|---|
| XOM | Exxon Mobil Corporation | 321,087.9 |
| B03MM4 | Royal Dutch Shell Plc Class B | 258,874.8 |
| CVX | Chevron Corporation | 215,579.0 |
| B15C55 | Total SA | 138,867.8 |
| 079805 | BP p.l.c. | 129,333.3 |
| 713360 | Statoil ASA | 71,953.8 |
| COP | ConocoPhillips | 61,233.1 |
| 714505 | Eni S.p.A. | 59,638.9 |
| EOG | EOG Resources, Inc. | 57,862.4 |
| OXY | Occidental Petroleum Corporation | 52,174.4 |
| PSX | Phillips 66 | 46,485.2 |
| VLO | Valero Energy Corporation | 38,603.4 |
| KMI | Kinder Morgan Inc Class P | 38,501.1 |
| MPC | Marathon Petroleum Corporation | 31,026.2 |
| APC | Anadarko Petroleum Corporation | 30,712.0 |
| PXD | Pioneer Natural Resources Company | 28,085.7 |
| 566935 | Repsol SA | 26,623.4 |
| WMB | Williams Companies, Inc. | 23,653.2 |
| OKE | ONEOK, Inc. | 22,301.2 |
| CXO | Concho Resources Inc. | 20,668.0 |

**Table 1B: Sample start and end dates**

| Symbol | Company Name | Start | End | No Obs |
|---|---|---|---|---|
| B03MM4 | Royal Dutch Shell Plc | 09-01-09 | 15-02-19 | 528 |
| CVX | Chevron Corporation | 06-02-09 | 15-03-19 | 528 |
| B15C55 | Total SA | 04-01-02 | 25-01-19 | 876 |
| 079805 | BP p.l.c. | 19-03-02 | 12-10-18 | 876 |
| 713360 | Statoil ASA | 19-04-02 | 25-01-19 | 876 |
| COP | ConocoPhillips | 14-06-02 | 22-03-19 | 876 |
| 714505 | Eni S.p.A. | 04-01-01 | 22-03-19 | 876 |
| VLO | Valero Energy Corporation | 07-06-02 | 15-03-19 | 876 |
| MPC | Marathon Petroleum Corporation | 10-01-03 | 18-01-19 | 876 |
| KMI | Kinder Morgan Inc Class P | 01-09-19 | 15-02-19 | 876 |
| PXD | Pioneer Natural Resources | 09-01-09 | 15-02-19 | 876 |
| 566935 | Repsol SA | 04-01-02 | 15-02-19 | 876 |
| CY11400 | America Energy IG 5Y CDS | 07-01-2011 | 19-04-19 | 433 |
| CY113360 | Europe Energy IG 5Y CDS B | 07-01-2011 | 19-04-19 | 433 |
| CY112030 | Asia EXJP Energy IG 5Y C | 07-01-2011 | 19-04-19 | 433 |

| Table 1C: America Energy IG 5R CDS index components | |
|---|---|
| **Company Name** | **Weight** |
| **XTO Energy Inc** | 2.857 |
| **ONEOK Partners LP** | 2.857 |
| **Enterprise Products Operating LLC** | 2.857 |
| **Pioneer Natural Resources Co** | 2.857 |
| **Energy Transfer Partners LP** | 2.857 |
| **Spectra Energy Capital LLC** | 2.857 |
| **Noble Energy Inc** | 2.857 |
| **Kinder Morgan Inc/DE** | 2.857 |
| **Kinder Morgan Energy Partners LP** | 2.857 |
| **Marathon Oil Corp** | 2.857 |
| **GlobalSantaFe Corp** | 2.857 |
| **Baker Hughes Inc** | 2.857 |
| **Suncor Energy Inc** | 2.857 |
| **Anadarko Petroleum Corp** | 2.857 |
| **Enbridge Energy Partners LP** | 2.857 |
| **ConocoPhillips** | 2.857 |
| **Hess Corp** | 2.857 |
| **Husky Energy Inc** | 2.857 |
| **Sunoco Inc** | 2.857 |
| **Plains All American Pipeline LP / PAA Finance Corp** | 2.857 |
| **Chevron Corp** | 2.857 |
| **Williams Partners LP/Old** | 2.857 |
| **Valero Energy Corp** | 2.857 |
| **Nabors Industries Inc** | 2.857 |
| **Halliburton Co** | 2.857 |
| **Occidental Petroleum Corp** | 2.857 |
| **Enbridge Inc** | 2.857 |
| **Repsol Oil & Gas Canada Inc** | 2.857 |
| **Devon Energy Corp** | 2.857 |
| **Exxon Mobil Corp** | 2.857 |
| **Encana Corp** | 2.857 |
| **Kerr-McGee Corp** | 2.857 |

| | |
|---|---|
| **Canadian Natural Resources Ltd** | 2.857 |
| **Apache Corp** | 2.857 |
| **TransCanada PipeLines Ltd** | 2.857 |

**Table 1D: Europe Energy IG 5Y CDS components**

| **Company Name** | Weight |
|---|---|
| **TOTAL SA** | 14.286 |
| **Technip SA** | 14.286 |
| **Royal Dutch Shell PLC** | 14.286 |
| **BP PLC** | 14.286 |
| **Eni SpA** | 14.286 |
| **Repsol SA** | 14.286 |
| **Statoil ASA** | 14.286 |

**Table 1E: Asia EXJP Energy IG 5Y**

| **Company Name** | **Weight** |
|---|---|
| **GS Caltex Corp** | 14.286 |
| **Nexen Energy ULC** | 14.286 |
| **Woodside Petroleum Ltd** | 14.286 |
| **Jemena Ltd** | 14.286 |
| **CNOOC Ltd** | 14.286 |
| **Petroliam Nasional Bhd** | 14.286 |
| **Reliance Industries Ltd** | 14.286 |

**Table 3: Summary Results:**
**This table summarizes time series explosive behaviour seen in the 12 Energy Corporates analysed. X denotes mild explosivity significant at the 5% level x* denotes mild explosivity significant at the 10% level and $x^{mb}$ denotes mild explosivity at 5% significance level but minimum bubble condition not satisfied**

| **Start** | Jun-04 | Jun-07 | Oct-08 | May-10 | Jul-14 | Jul-15 | Jul-17 |
|---|---|---|---|---|---|---|---|
| **End** | Dec-07 | Sep-08 | Jun-09 | Dec-11 | Jun-15 | Jul-16 | Mar-19 |
| Royal Dutch Shell Plc | | | | x* | | x | x* |
| Chevron Corporation | | | | $x^{mb}$ | | x* | |
| Total SA | | x | x | | | $x^{mb}$ | |
| BP p.l.c. | | x x | | | | $x^{mb}$ | |
| Statoil ASA | x* | x | x | x* | | $x^{mb}$ | |
| ConocoPhillips | | x | | x* | | x | |
| Eni S.p.A. | | x | | | | | |
| Valero Energy | x* | x | | | | $x^{mb}$ | |
| Marathon Petroleum | | x x | | | | x | |
| Kinder Morgan | | | | x | | x | |
| Pioneer Natural | | | x | $x^{mb}$ | | | x |
| Repsol SA | | | x | x | | x | x |
| America Energy IG | | | | | X | X | X |
| Europe Energy IG | | | | | X | X | X |
| Asia EXJP Energy IG | | | | | | X | X |

**Table 4A:**
**Estimated start and end dates for periods of mildly explosive price behaviour for weekly CDS prices of Royal Shell, Chevron, Total SA and BP PLC**

| Standard Critical Values | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Royal Shell** | | **Chevron** | | **Total SA** | | **BP PLC** | |
| **Start** | **End** | **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 28-05-10 | 09-07-10* | 26-08-11 | 16-09-11$^{mb}$ | 23-11-07 | 11-01-08 | 23-11-07 | 14-01-08 |
| 15-01-16 | 26-02-16 | 18-12-15 | 08-04-16 | 01-02-08 | 04-04-08 | 01-02-08 | 04-04-08 |
| 21-07-17 | 01-09-17* | 26-10-18 | 07-12-18 | 12-12-08 | 06-02-09 | 12-12-08 | 06-02-09 |
| | | | | 12-02-16 | 26-02-16$^{mb}$ | 19-02-16 | 26-02-16$^{MB}$ |
| **Wild Bootstrapped critical values** | | | | | | | |
| **Start** | **End** | **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 19-2-14 | 30-01-15 | 09-09-11 | 16-9-11$^{MB}$ | 08-2-08 | 04-04-08 | 08-02-08 | 04-04-08 |
| 15-1-16 | 26-2-16* | 18-12-15 | 29-01-16 | 12-12-08 | 03-01-09 | 12-12-08 | 03-01-09 |
| | | | | 12-02-16 | 19-02-16 | | |

This table reports mildly explosive periods in the weekly Royal Shell, Chevro**n, Total SA, BP PLC** CDS premiums using the PSY procedure with 5% size *Only significant at the 10% level: $^{mb}$ implies that the minimum bubble condition is not satisfied

**Appendix 4: Date stamping on the basis of BSADF statistics**

**Table 4B:**

**Estimated start and end dates for periods of mildly explosive price behaviour for weekly CDS prices of Statoil ASA, Conoco Phillips, Eni S.p.A and Valero Energy**

| **Statoil ASA** | | **Conoco Phillips** | | **Eni S.p.A** | | **Valero Energy** | |
|---|---|---|---|---|---|---|---|
| Start | **End** | **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 05-3-04 | 30-04-04* | | | | | | |
| 17-09-04 | 05-11-04 | | | | | | |
| 25-01-08 | 28-03-08 | 19-11-04 | 07-01-05 | 08-02-08 | 28-03-08 | 11-01-08 | 04-04-08 |
| 28-11-08 | 16-01-09 | 15-02-08 | 04-04-08 | 28-11-08 | 13-02-09 | 1-10-2008 | 06-02-09 |
| 02-09-11 | 07-10-11* | | | | | | |
| 15-01-16 | 22-01-16 $^{mb}$ | 26-08-11 | 14-10-11* | | | 19-2-2016 | 20-2-2016$^{MB}$ |
| 12-02-16 | 19-02-16$^{mb}$ | 08-01-16 | 26-02-16 | | | 23-11-18 | 07-12-2018$^{MB}$ |
| **Panel B: Wild Bootstrapped critical values** | | | | | | | |
| **Start** | **End** | **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 05-03-04 | 30-04-04 | | | | | | |
| 12-02-08 | 28-03-08 | 15-02-08 | 04-04-08 | 15-02-08 | 04-04-08 | 15-02-08 | 04-04-08 |
| 12-02-16 | 19-02-16$^{mb}$ | 08-01-16 | 05-02-16$^{mb}$ | | | 21-11-08 | 06-02-09 |
| | | | | | | 19-02-16 | 26-02-2016 |

This table reports mildly explosive periods in the weekly Statoil ASA, Conoco Phillips**, Eni SpA, Valero Energy** CDS premia using the PSY procedure with 5% size *Only significant at the 10% level: $^{mb}$ implies that the minimum bubble condition is not satisfied

**Table 4C:**

Estimated start and end dates for periods of mildly explosive price behaviour for weekly CDS prices of Marathon Petroeum, Kinder Morgan, Pioneer Natural and Repsol SA

| **Marathon Petroleum** | | **Kinder Morgan** | | **Pioneer Natural** | | **Repsol SA** | |
|---|---|---|---|---|---|---|---|
| **Start** | **End** | **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 25-01-08 | 04-04-08 | 12-08-11 | 14-10-11 | 30-09-11 | 28-10-11[MB] | 28-11-08 | 16-01-09 |
| 12-09-08 | 06-02-09 | 07-08-15 | 18-09-15 | | | 11-05-12 | 20-07-12 |
| 18-12-15 | 04-03-16 | | | | | | |
| | | | | 30-11-18 | 11-01-19 | 15-01-16 | 04-03-16 |
| **Panel B: Wild bootstrapped critical values** | | | | | | | |
| Start | End | Start | End | Start | End | Start | End |
| 8-02-08 | 28-03-08 | 29-07-15 | 14-10-11 | 17-06-11 | 29-07-11 | 28-11-08 | 16-01-09 |
| 10-10-08 | 28-11-09 | | | 12-08-11 | 28-10-11 | | |
| 15-01-16 | 04-03-16 | 31-07-15 | 18-09-15 | 07-12-18 | 19-01-19* | 22-01-16 | 11-03-16 |

This table reports mildly explosive periods in the weekly **Marathon Petroleum, Kinder Morgan, Pioneer Natural and Repsol SA** premia using the PSY procedure with 5% size *Only significant at the 10% level: [mb] implies that the minimum bubble condition is not satisfied

**Table 4D : Energy CDS indexes**

Estimated start and end dates for periods of mildly explosive price behaviour for weekly sectorial CDS indexes **American Energy IG 5Y, Europe Energy IG 5Y, Asia Ex Japan IG 5Y**

**Panel A**
**Standard Critical values**

| **American Energy IG 5Y** | | **Europe Energy IG 5Y** | | **Asia Ex Japan IG 5Y** | |
|---|---|---|---|---|---|
| **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 12-12-2014 | 6-02-15 | | | | |
| 18-12-2015 | 04-03-2016 | 22-01-2016 | 04-03-2016 | 28-08-2015 | 13-11-2016 |
| | | | | 22-1-2016 | 18-3-2016* |

**Panel B**
**Wild bootstrapped critical values**

| **American Energy IG 5Y** | | **Europe Energy IG 5Y** | | **Asia Ex Japan IG 5Y** | |
|---|---|---|---|---|---|
| **Start** | **End** | **Start** | **End** | **Start** | **End** |
| 05-12-2014 | 06-02-2015 | | | 28-08-2015 | 23-10-2015 |
| 18-12-2015 | 4-03-2016 | 22-01-2016 | 19-02-2016[mb] | No bubble | |

This table reports mildly explosive periods in the weekly for American Energy IG 5YR CDS, Europe Energy IG 5Y CDS using the PSY procedure with 5% size *Only significant at the 10% level: [mb] implies that the minimum bubble condition is not satisfied

**Table 4F: Estimated start and end dates for periods of mildly explosive price behaviour for 10 YR real yields**

| Start | End |
|---|---|
| **15-10-10** | 22-10-10[mb] |
| **28-6-13** | 12-7-13[mb] |

This table reports mildly explosive periods in weekly US 10 year real yields calculated as the 10 year nominal yield minus the USBREAK index. The PSY procedure is used with 5% size. *Only significant at the 10% level, [mb] implies that the minimum bubble condition is not satisfied

**Table 4G:**

**Estimated start and end dates for periods of mildly explosive price behaviour for crude oil NYMEX WTI futures and and ICE front month brent futures adjusted standard and wild bootstrapped critical values**

| | | | |
|---|---|---|---|
| **Standard Critical Values** | | | |
| **WTI Nominal Futures** | | **Brent Nominal futures** | |
| **Start** | **End** | **Start** | **End** |
| 16-5-08 | 25-07-08 | 16-5-08 | 18-07-08 |
| | | 21-01-11 | 06-05-11 |
| 24-10-14 | 06-02-15 | 14-11-14 | 06-02-15 |
| **Wild Bootstrapped Critical Values** | | | |
| **WTI Nominal futures** | | **Brent Nominal Futures** | |
| **Start** | **End** | 13-06-2008 | 18-7-2008*mb |
| | | 04-03-11 | 06-05-11 |
| 12-12-2014 | 03-01-2015 | 19-12-2014 | 6-2-2015 |

This table reports mildly explosive periods in the weekly for future WTI and brent nominal prices using the PSY procedure with 5% size *Only significant at the 10% level: [mb] implies that the minimum bubble condition is not satisfied

**Appendix 5: Time series and panel regressions**

**Table 5: Time series regressions of price fundamental relationships between autoregressive estimates**

| | *Panel I* | | | | *Panel II* | | | |
|---|---|---|---|---|---|---|---|---|
| | $\varphi_{CDS=AMINDEX}$ | | | | $\varphi_{CDS=EUINDEX}$ | | | |
| $\varphi_0$ | 0.002 | -0.000 | 0.002 | 0.006 | -0.011 | -0.012 | -0.011 | -0.012 |
| | (0.365) | (-0.114) | (0.361) | (1.412) | (-1.983) | (-2.239) | (-1.906) | (2.604) |
| $\varphi_{WTI}$ | 0.982$^{***}$ | | | | 0.742$^{**}$ | | | |
| | (5.723) | | | | (2.835) | | | |
| $\varphi_{BRENT}$ | | 1.344$^{***}$ | | | | 0.723$^{**}$ | | |
| | | (6.319) | | | | (2.567) | | |
| $\varphi_{US10}$ | | | -0.158$^{*}$ | | | | -0.140$^{*}$ | |
| | | | (-2.071) | | | | (-1.703) | |
| $\varphi_{CDS=EUINDEX}$ | | | | 0.374$^{***}$ | | | | |
| | | | | (9.617) | | | | |

| | | | |
|---|---|---|---|
| $\varphi_{CDS=AMINDEX}$ | | | $0.556^{**}$ <br> (2.311) |

This table presents results from estimating price fundamental OLS regressions between recursive autoregressive estimates as specified in equation (). T-statistics are in parenthesis with Newey-West standard errors, while *, **, and *** represent the 10%, 5% and 1% significance.

Table 6: Weekly Panel regression estimation for time dependent ADF variables for the 2011-2019

| | $\emptyset_{cds,i=3,t}$ | $\emptyset_{Brent,t}$ | $\emptyset_{US10,t}$ |
|---|---|---|---|
| $\emptyset_{US10,t}$ | 0.0101 <br> (0.924) | $-0.081^{***}$ <br> (-3.271) | |
| $\emptyset_{Brent,t}$ | $0.904^{***}$ <br> 0.000 | | -0.102 <br> (-3.278) |
| $\emptyset_{CDS,i=3,t}$ | | $0.044^{***}$ <br> (6.999) | 0.003 <br> (0.461) |

This table reports estimates of the panel OLS regression specified in equations 9, 10 and 11.
Results give OLS estimates for the following dependent variables
b) $\varphi_{CDS,i=3,t}$ which is the autoregressive coefficient for i=3 CDS energy indexes (panel II).
c) $\varphi_{Brent,t}$ the autoregressive coefficient corresponding to the brent crude oil futures prices (Panel III)
d) $\varphi_{US10,,t}$ which is the autoregressive coefficient corresponding to the US 10 year real yield
Data includes weekly observations for each variable
Standard errors are adjusted for autocorrelation. ***, ** and * indicate a significance
level of 1%, 5% and 10%.

Table 7: Panel regression of equation 13 for the 2011-2019 for $RAT_{i,T}$

$$RAT_{i,t} = \gamma_{0,t} \quad + \gamma_{1i,t}\widehat{\emptyset}_{CDS,i,t} + \gamma_{2i,t}\hat{\beta}_{2,t} + v_{i,t}$$

Values represented by CAPEX/DEBT (Panel I) standardized DEBT-index (Panel II) DEBT/EBITDA (Panel III).

| | $RAT_{Capex/debt}$ | $RAT_{debt/EBITDA}$ |
|---|---|---|
| | ***Panel I*** | ***Panel II*** |
| $\Phi_{CDS,i=12,t}$ | -0.177*** | -0.320 |
| | (-9.866) | (-0.067) |
| $\beta_{2,t}$ | 0.114*** | 6.567*** |
| | (31.303) | (6.650) |
| R-squared | 0.2533 | 0.001 |

This table presents the results from panel estimation of equation 12 and 13 over the sample period from October 2011 to December 2019 on a weekly basis. Entity and time effects are included in the estimation. The panel OLS routine of python is applied where quarterly values of $\Phi_{CDS}$ are calculated as 12 week averages and quarterly values of $\beta_{2,t}$ are calculated as 12 week averages of rolling estimates
Standard errors are adjusted for autocorrelation. ***, ** and * indicate a significance level of 1%, 5% and 10%.

## Appendix 2: Figures and Graphs

### Section A: CDS spread and Fundamental price levels

Fig 1A: Brent crude oil futures weekly prices and 10 yr real US bond yields

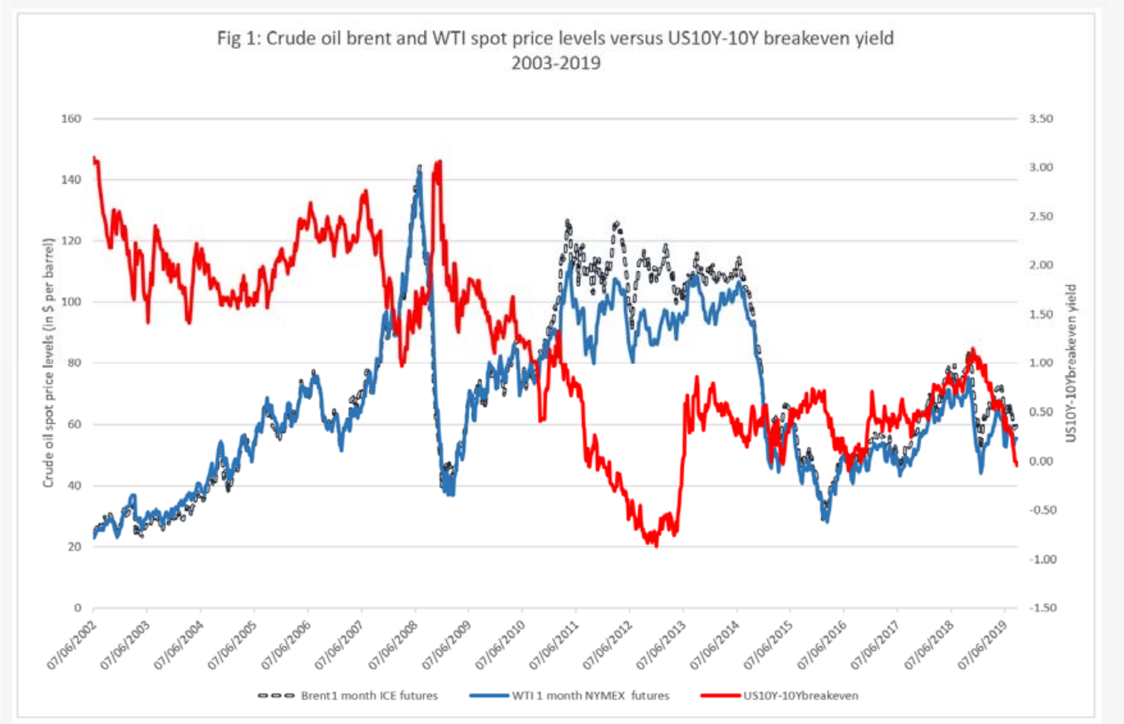



Fig 1B: Time series evolution of CDS premia: Royal Dutch Shell, Chevron Corporation, Kinder Morgan, and Pioneer Natural Resources: Jan 2009-Jan2019

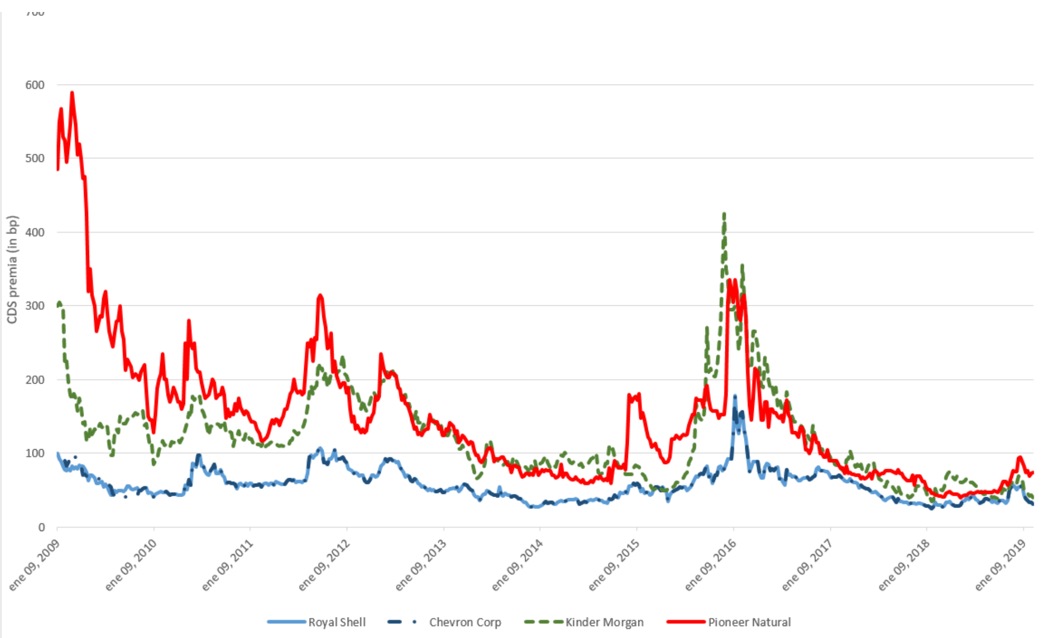


Fig 1C: Time series evolution of CDS premia: Total SA, Stat oil ASA, Con Phillips, Eni S. p. A, Valero Energy, Marathon Petroleum, Repsol SA: Jan 2009-Jan2019

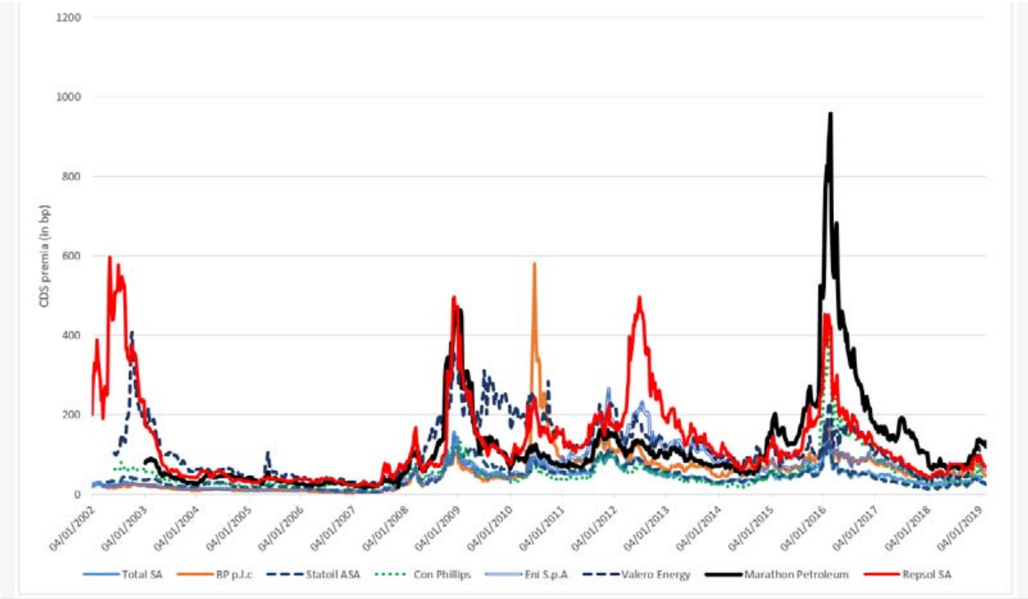
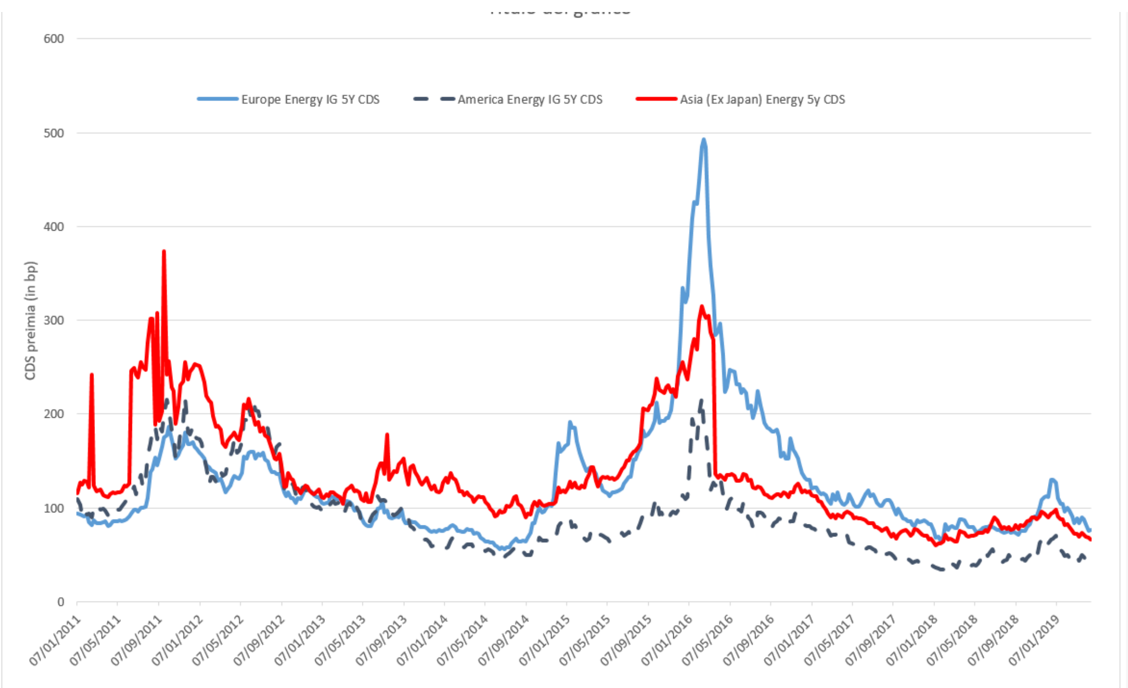



Fig 1D: Time series plot of four Energy CDSs indexes Europe Energy IG 5yr CDS, America Energy IG, 5YR CDS, Asia Energy 5Y CDS




**Section 2: BSADF sequences and 5% critical values for individual energy corporates**

Fig 2A: Royal Shell 5 YR CDS BSADF sequence

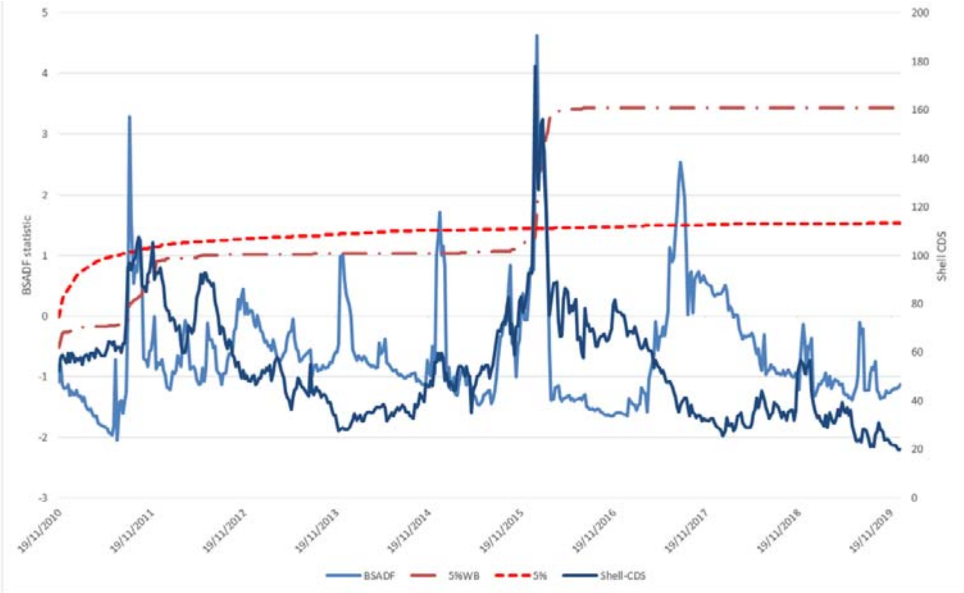



Fig 2B.Chevron 5 YR CDS BSADF sequence

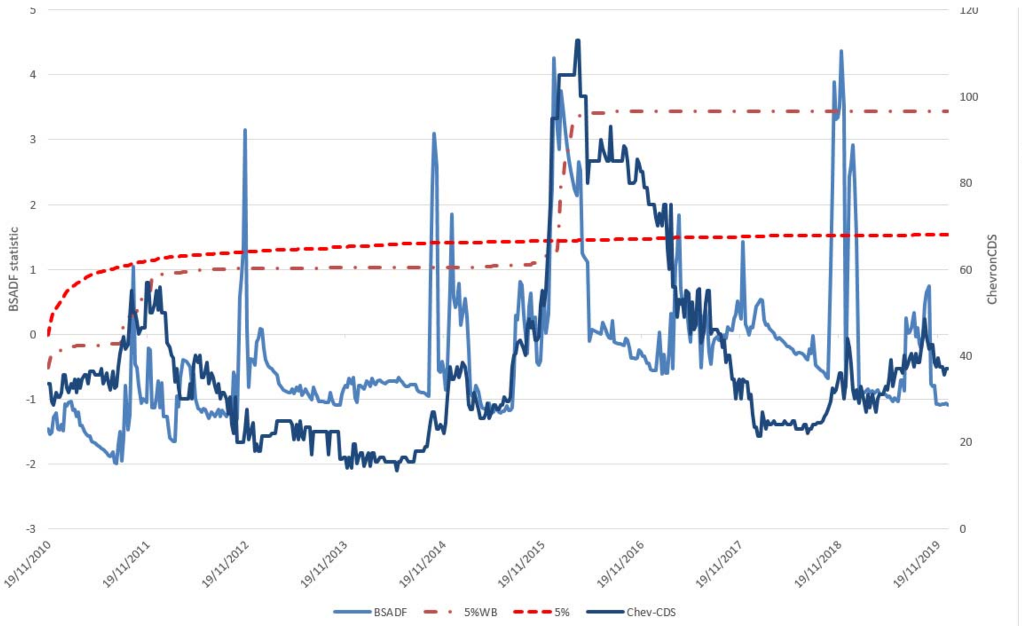


Fig 2C: Total 5 YR CDS BSADF sequence

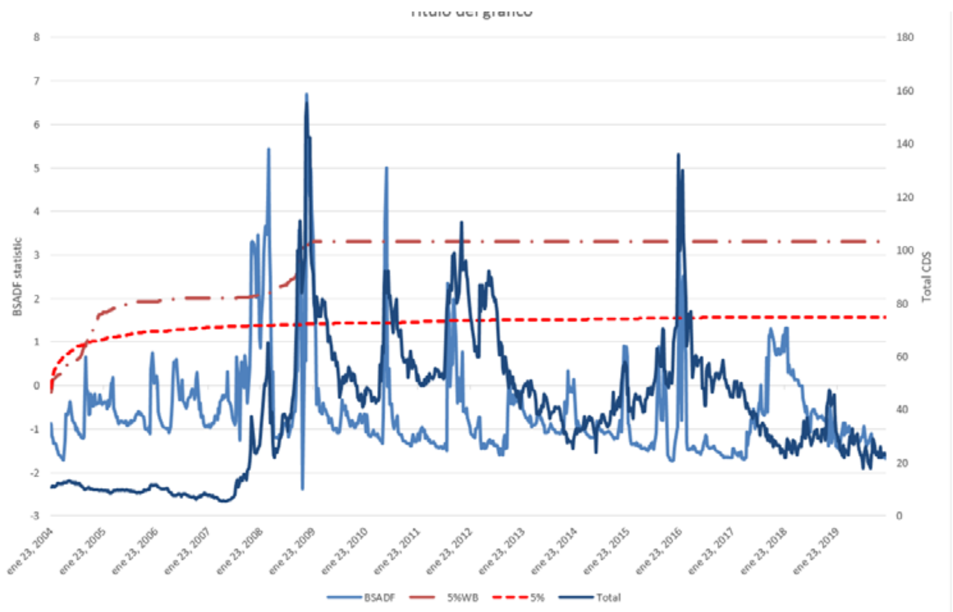



Fig 2D: BP 5 YR CDS BSADF recursive sequence

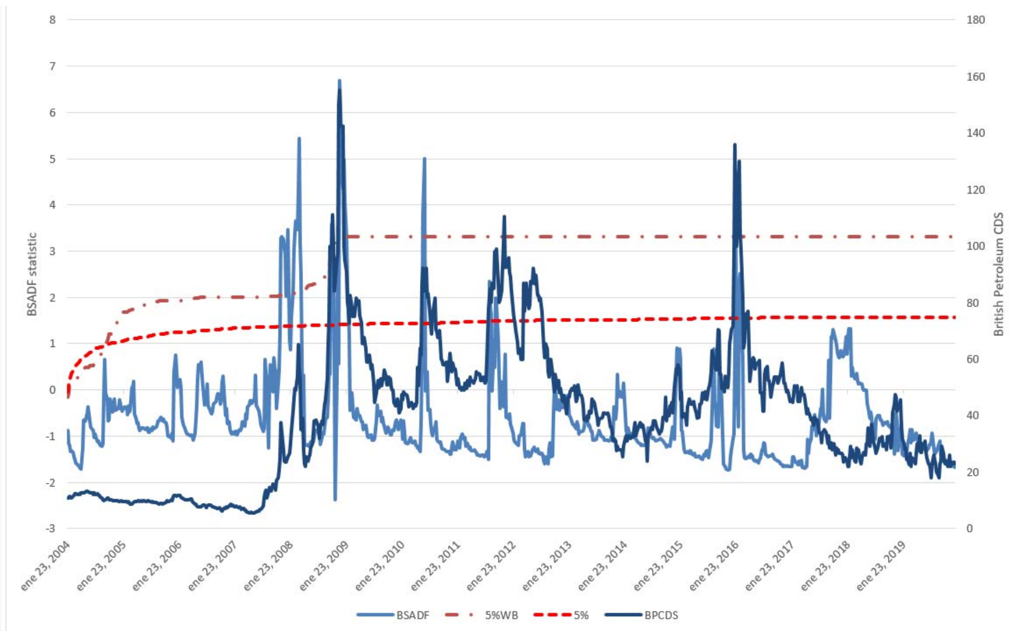


Fig 2E: Statoil 5 YR CDS BSADF recursive sequence

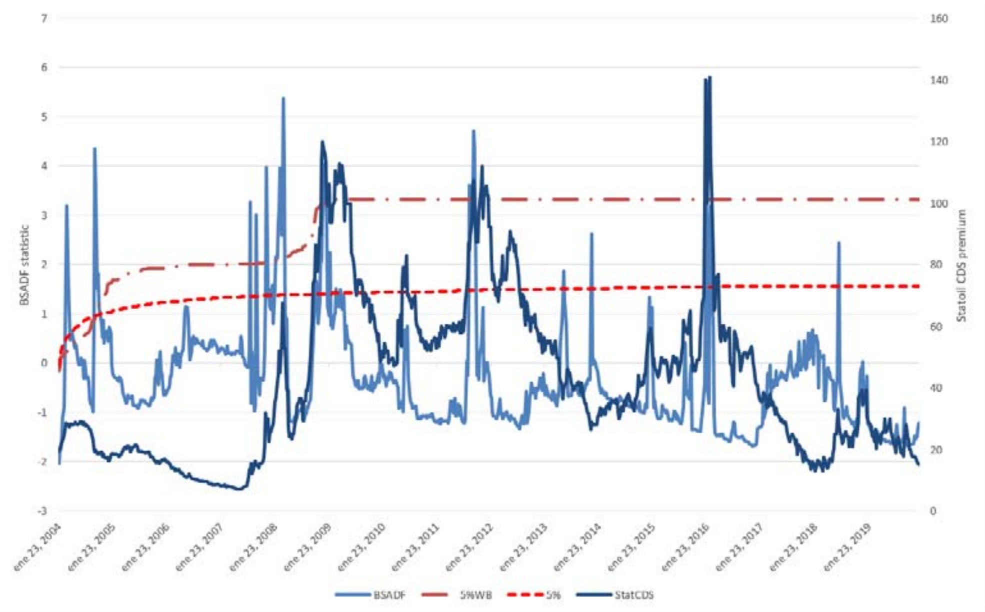



Fig 2F: Con Phillips 5 YR CDS BSADF recursive sequence

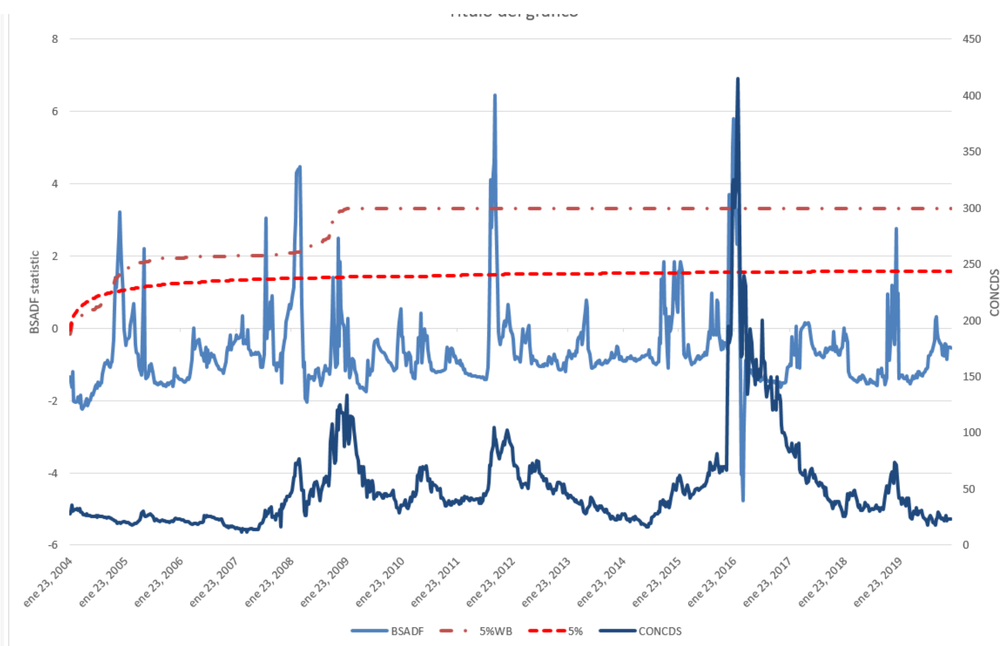


Fig 2G: Eni 5YR CDS BSADF sequence

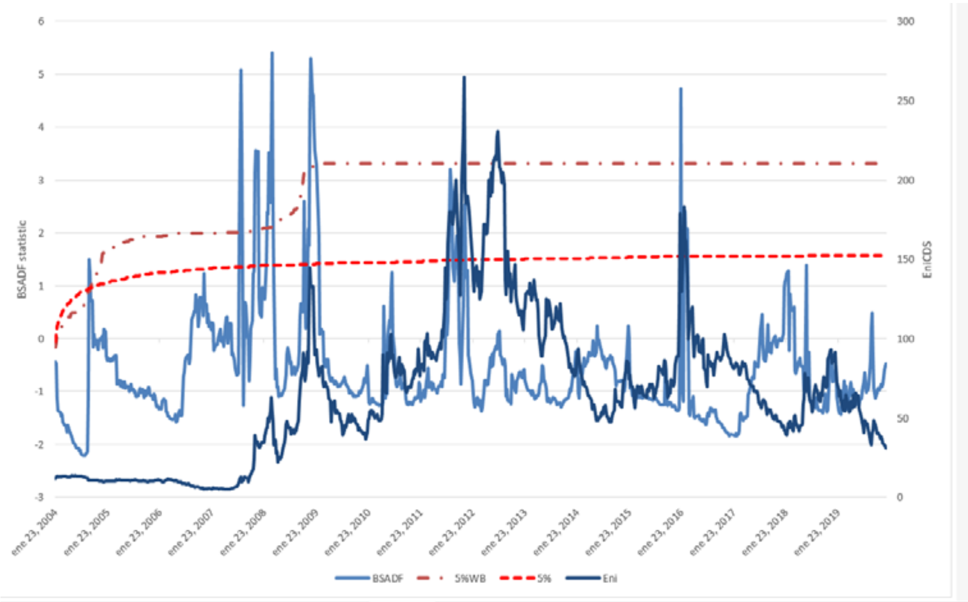



Fig 2H: Valero 5YR CDS BSADF sequence

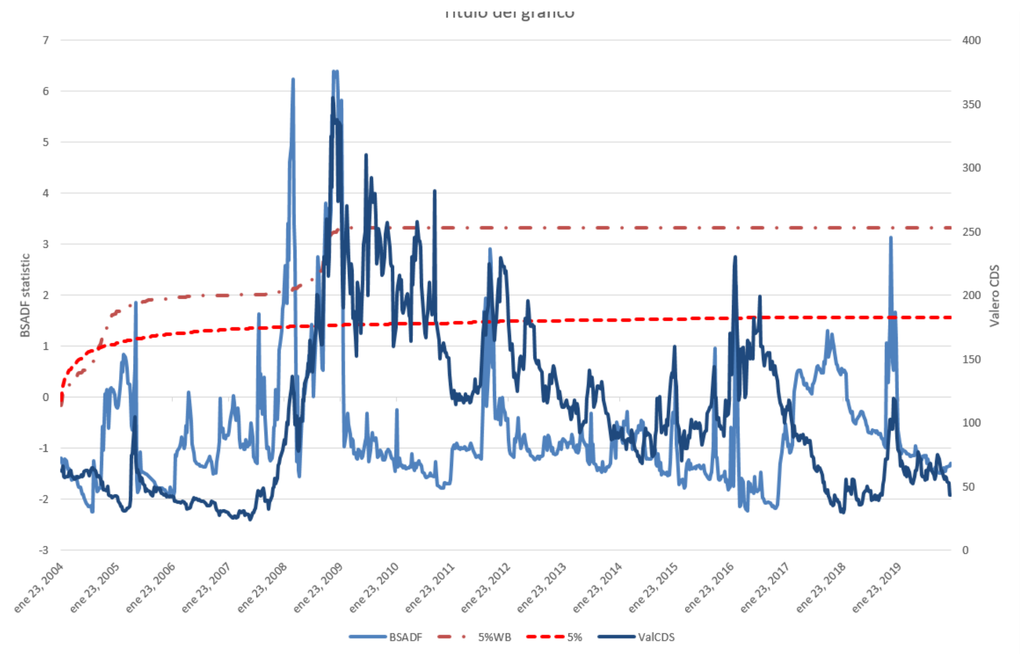



Fig 2I:  Marathon 5 YR CDS BSADF recursive sequence

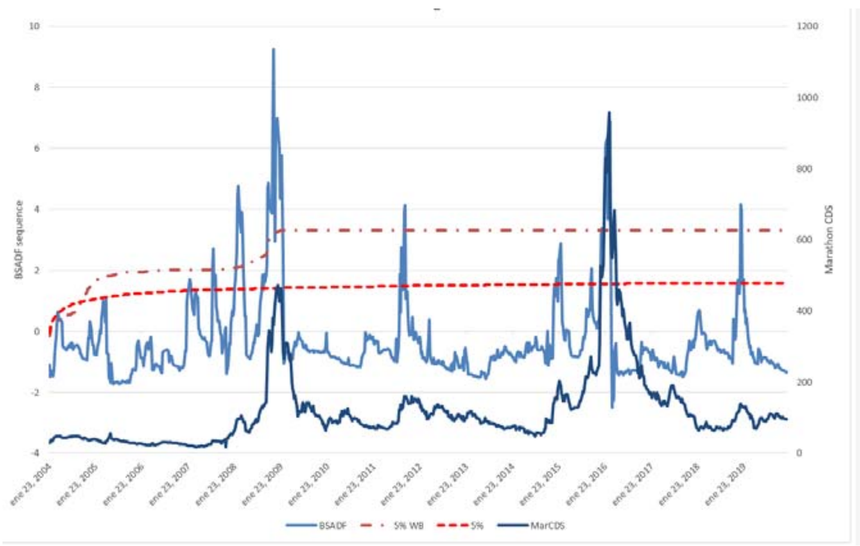



Fig 2J: Kinder 5 YR CDS  BSADF recursive sequence

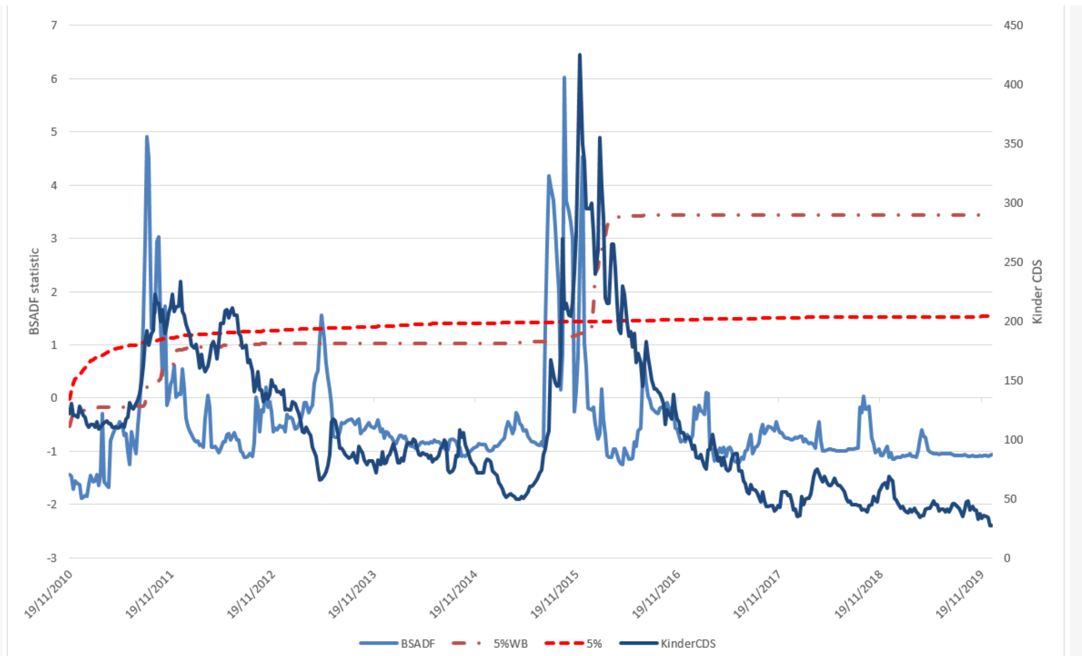



Fig 2K: Pioneer BSADF 5 YR CDS  recursive sequence

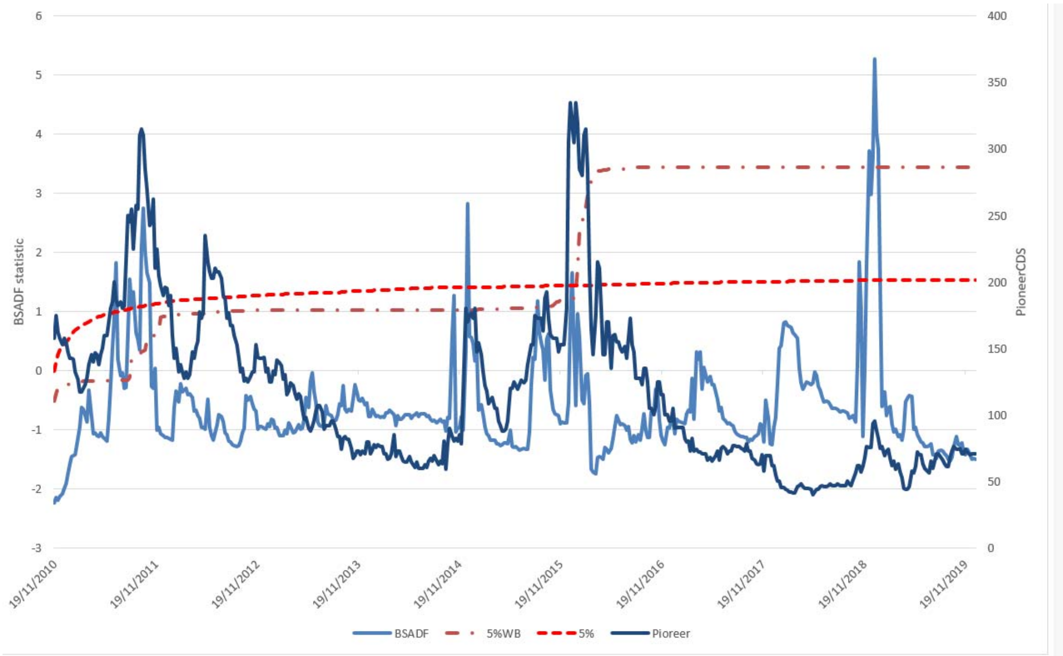
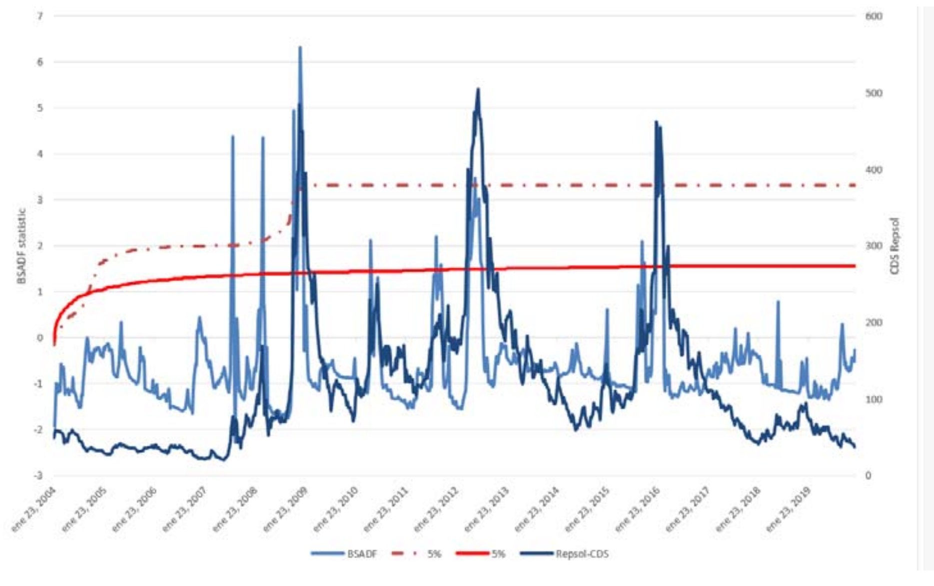



Fig 2L: Repsol 5 YR CDS recursive BSADF sequence




**Section 3: BSADF sequences and 5% critical values for CDS energy sectorial indexes**

Fig 3A : BSADF sequence: American ENERGY IG 5 yr CDS

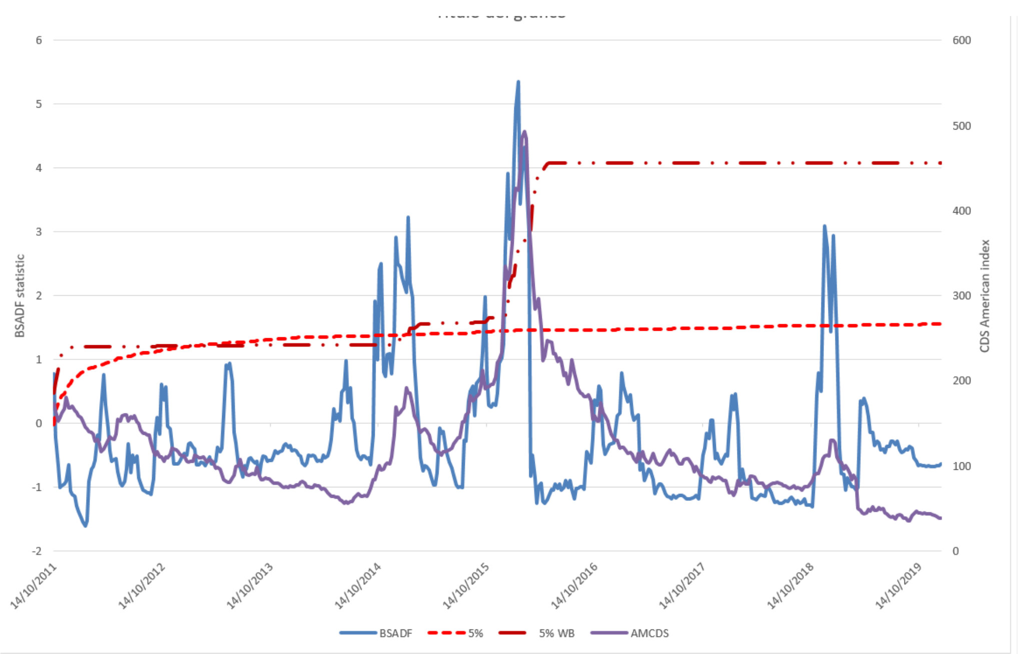



Fig 3B: BSADF sequence EUROPE IG CDS index

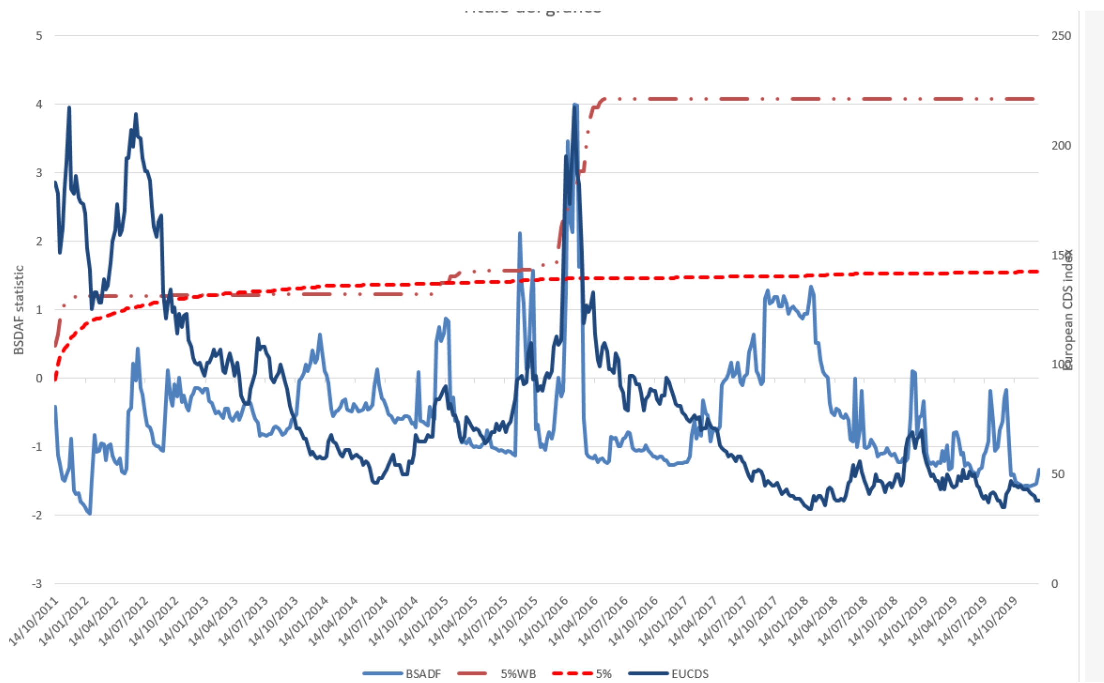
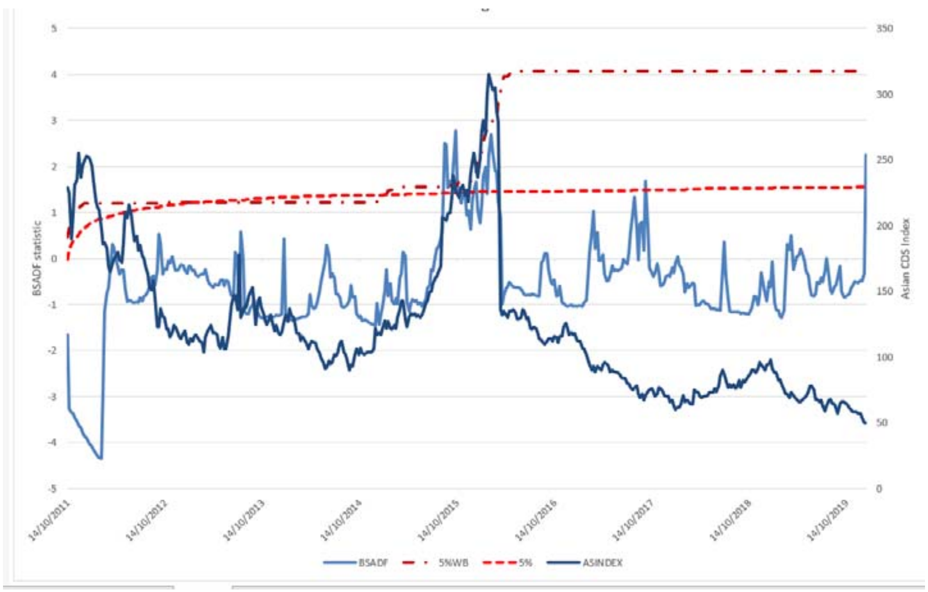


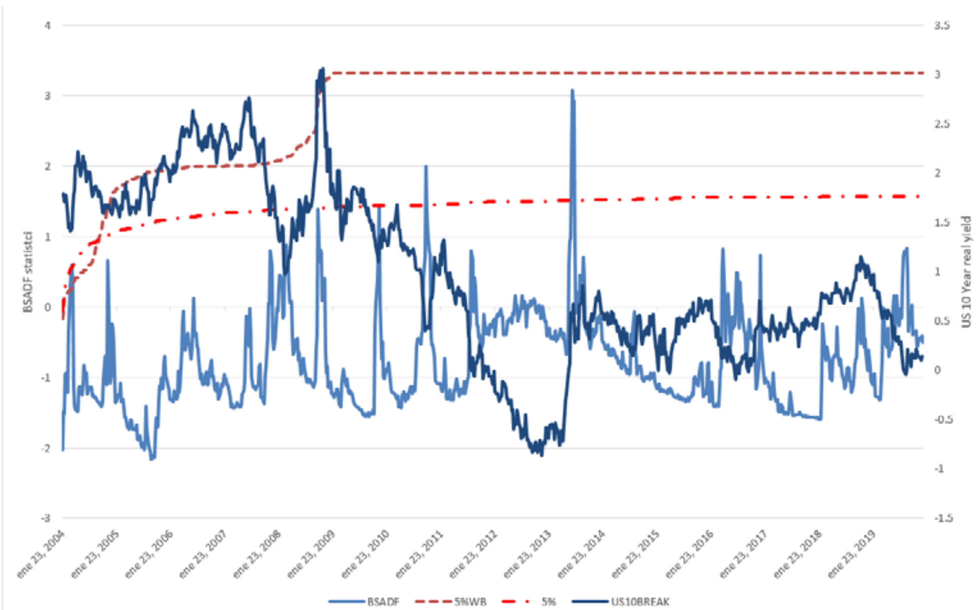

Fig 3C: BSADF sequence Asia ex Japan IG CDS index




**Section 4: BSADF sequences and 5% critical values for energy CDS fundamentals**

**US real Treasury Yields**

Fig 4A BSADF recursive sequence 10yr real US Treasury yield minus 5 year breakeven



**Crude oil futures prices**

Fig 4B: WTI crude oil nominal spot BSADF sequence

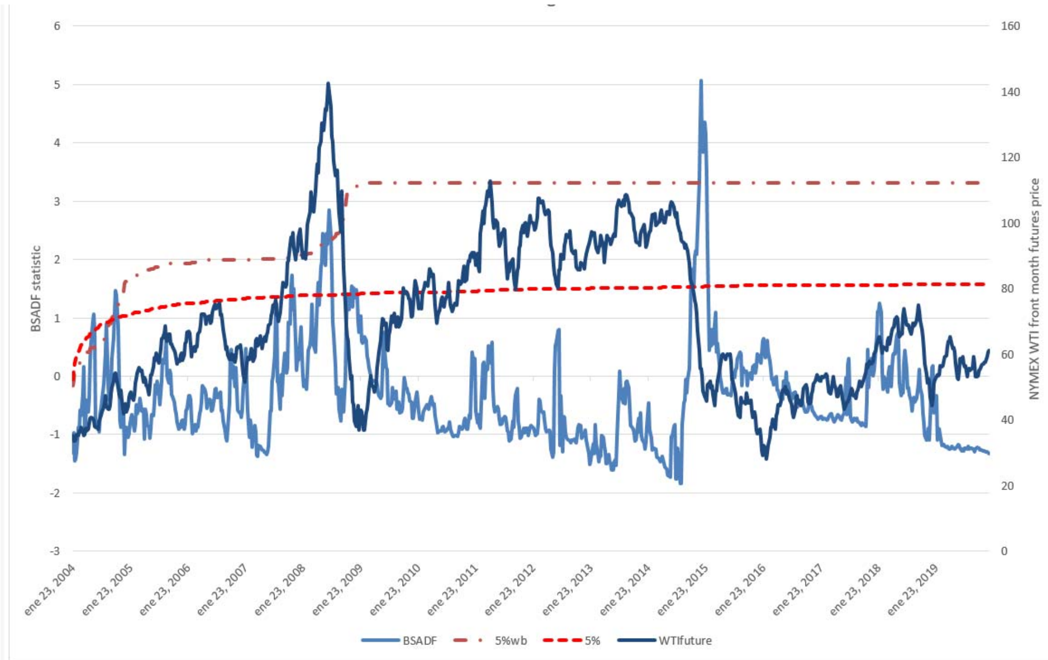



Fig 4C: Brent crude oil spot BSADF recursive sequence