The systemic risk of the US Oil and Natural Gas companies *

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Abstract

We analyze the evolution of the systemic risk impact of Oil and Natural Gas companies since 2000. This period is characterized by several events that affected the energy sources markets: the real effect of the global financial crisis, the explosion of shale production, the diffusion of the Covid-19 pandemic. The price of oil and natural gas showed extreme swings impacting on companies' financial situation, which, accompanied by the technological developments for shale production, had an impact on the debt issuance and on the overall risk level of the Oil and Natural Gas sector. By studying the systemic impact of Oil and Natural Gas companies on the financial market risk, measured by the ΔCoVaR, we do observe that in the most recent decade their role is sensibly increasing compared to 2000-2010, even accounting for the possible effect associated with the increase in companies' size. In addition, our results show evidence of a decreasing relevance of traditional drivers of systemic risk, suggesting that additional factors might be present. Finally, when focusing on the Covid-19 impact, we document its relevant role in fueling the increase of the Oil and Natural Gas companies systemic impact.

Keywords: Systemic risk,Oil and Natural Gas, Fossil Fuel, Energy

J.E.L. classification: Q43; Q40; G10; C21; C58.

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1 Introduction

According to the US Energy Information Administration (EIA) over the past decade the US oil output is more than doubled. In 2019, United States was the top oil producer with 19% of share over the total world production. Oil companies financed their growth and their drilling activities engaged in bond issuance rated with low grades by credit agencies. According to data at the beginning of 2020, North American oil exploration and production companies have $ 86 billion in debt that will mature between 2020 and 2024, and pipeline companies have an additional $123 billion in debt coming due over the same period, according to Moodys.[1] Oil and gas companies are price takers in the global market for crude oil. This means that oil and gas companies that do not pursue risk management via hedging or other financial engineering activities can experience erratic or significant energy price volatility which in turn could impact their cash flows Fusaro (1998). At the same time the global economic conditions are not encouraging: Oil companies must afford different expected and unexpected difficulties that have pulled down the oil price under the marginal cost of production for US companies. The drop of crude oil price could be related to the following reasons : (i) The OPEC and Russia agreed to raise the oil production in order to maintain their market share;(ii)the European Commission aims to accelerate the clean energy transition and (iii) the outbreak of Covid-2019 pandemic plummeted the global demand of crude oil to minimum level. To this pertain we don't know in which extent the Oil and Natural Gas sector can continue to absorb these shocks but unfortunately the number of fallen angels in the Oil sector have been increasing since 2015[2].

Although nowadays the financial system is more resilience than it was in 2007, we should not forget the lesson we have learned from the global financial crisis: idiosyncratic shocks can aggregate each other and become systemic under precise conditions. Can the Oil and Natural Gas sector turmoil be the fuse for a new crisis and threaten the stability of financial system? In this paper we investigate the systemic risk of Oil and Natural Gas sector by looking at the evolution over time and at the determinants of the indicator put forward in Adrian and Brunnermeier (2016), the Δ Conditional Value-at-Risk ($\Delta - CoVaR$). The advantage of the $\Delta - CoVaR$ is that it enables us to determine the impact of a single Oil and Natural Gas company on a proxy of the financial market (the system) conditional to the distress in the company. Moreover, the methodological approach allows to control for possible state variables when building the

[1] https://www.nytimes.com/2020/12/03/business/opec-russia-oil-production.html

[2] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/s-p-global-fallen-angels-count-surges-to-highest-since-2015-58071556

indicator and to correlate the estimated indicators in the cross-section of Oil and Natural Gas companies with possible risk and impact drivers. This second step if particularly relevant as it enables us to identify the drivers of the increase in the oil and gas sector systemic risk.

By focusing on a panel of companies active, from 2000 to 2021, in the oil an gas sector, including support activities, and accounting for the role played by a selection of risk drivers, including both market-wide and company-specific variables we derive interesting insights. First of all, by combining the evolution of the shale extraction with the break identified in the oil prices by Caporin et al. (2019), we decide to focus on two distinct periods, 2000-2010 and 2011-2021. The comparison between these two sub-samples allows to identify a relevant difference in the debt issuance of oil and gas companies, an aspect that could have a relevant impact on the sector's systemic risk. This partly correlates with the changes observed in the risk indicators when contrasting the two periods. More interesting are the evidence associated with the role played by drivers of the ΔCoVaR variation. In fact, we show that the company size plays a relevant non-linear role in shaping the companies impact on the market systemic risk: the oil and gas companies impact on the systemic risk in due to larger companies in the first period but it expands to smaller companies in the 2011-2021 sample. Robustness checks confirm our findings.

The paper is structured as follows. In Section 2 we review the related literature and we present an overview of the US corporate debt market by sector. In Section 3 we review the methodology to compute the systemic risk measure (Δ CoVaR) while In Section 4 we describe the data we use in the empirical analysis. In Section 5 we investigate the drivers used for predicting the Δ CoVaR measure and in Section 6 we gather empirical result and our inference. We close the paper with a robustness analysis, in Section 7, and with final remarks in Section 8.

2 Literature review and institutional setting

Nowadays, the global challenges afforded by the US Oil and Natural Gas sector are becoming more complex, harder than ever. In this respect, it is crucial to investigate the drivers affecting the Oil and Natural Gas companies and if the sector is resilient enough to not threaten the financial stability. Evaluating the interdependence between the oil sector, and its structural/technological, economic and financial risk drivers, is thus of paramount importance. Sadorsky (2001) shows that exchange rates, crude oil prices and interest rates have large and significant

impacts on stock price returns in the Canadian Oil and Natural Gas industry. Faff and Brailsford (1999) document a positive and significant impact of oil prices on Australian Oil and Gas industry equity returns as well as El-Sharif et al. (2005) find that gas price and oil price has a positive effects on the UK Oil and Gas companies. The structure of the industry is also important: vertical drilling was the predominant technology in the U.S. oil production until the first decade of the 21-st century. However, all three technologies (directional, vertical and horizontal trajectory drilling) have been used in the extraction of hydrocarbons, and drilling rig count is considered a key indicator of the industry's health, see Apergis et al. (2021). Nevertheless drilling is capital intensive since the companies must finance their investment that inevitably bring other elements of risk .Howard and Harp Jr (2009) suggest that for a complete evaluation of the risk, companies characteristic as ratios, debt should be in place with the drivers mentioned before.

The transition to a lower carbon economy could make more gloomy and uncertain the future of Oil and Natural Gas firms. From this angle, according to Diaz-Rainey et al. (2021), transition risks could affect the Oil and Natural Gas sectors. These include: (i) higher costs in finding and extracting new oil and gas reserves; (ii) low oil prices as found by Basher et al. (2018); (iii) the falling cost of renewable energy generation; (iv) the switch to electric vehicles underpinned by technological improvements to batteries and decreasing vehicle and battery costs; (v) environmental minded investors affecting demand for petrochemicals see Fama and French (2007); (vi) carbon pricing and taxation schemes. Diaz-Rainey et al. (2021) found that the sign of the Paris Agreement had a large negative impact for the Oil and Gas sector. Monasterolo and De Angelis (2020) found that the after the Paris Agreement the high carbon stocks became less appealing for the investors. An eventual and realistic contraction of Oil and Natural Gas demand could reduce the cash flows and the margin of profit for these firms that are already in distress.

In order to frame the position of the US Oil and Natural Gas sector within the US debt market, we retrieve from Dealogic DCM, the amount at issuance of US bonds. The analysis shows that the most active issuers in the US bond market are governmental issuers and financial corporations.[3] In particular, during the time range 2000-2010 the amount of bonds issued by financial corporations was 15.3 trillion of dollars (T$), followed by the government with 7.3 T$, and non-financial corporations reaching a total of 3.4 T$. The debt structure changed after 2010: financial institutions substantially reduced the issuance during 2011-2020.[4] The government lead

[3]Municipal and sovereign bonds are included under the label *government*.

[4]The choice of focusing on those two periods is motivated in the empirical analyses included in Section 4.

the issuance with roughly 19 T$ followed by financial corporations 9.3 T$, while non-financial companies sum up to 7.7 T$. The first consideration we derive from these figures is that the amount at issuance is increased from the first (2000-2010) to the second (2011-2020) period as a consequence of the behavior of the Federal Reserve that kept down the interest rate. Figure 1 shows the breakdown of the amount at issuance by global industry group for each period. The Oil and Natural Gas companies raised a capital of 251 Bn $ in the first period, the fifth sector by issued volume. Utility & Energy was the most active sector among the non-financial corporations with 515 Bn $. In the second period, we observe a generalized expansion of bonds' issuance, especially for Oil and Natural Gas firms, that increased the amount of issuance by 134% or peaking at 589 Bn $, the fifth sectors in terms of amount issued. Computer & Electronics with 941 Bn$ is the most active sectors among the non-financial corporations.[5]

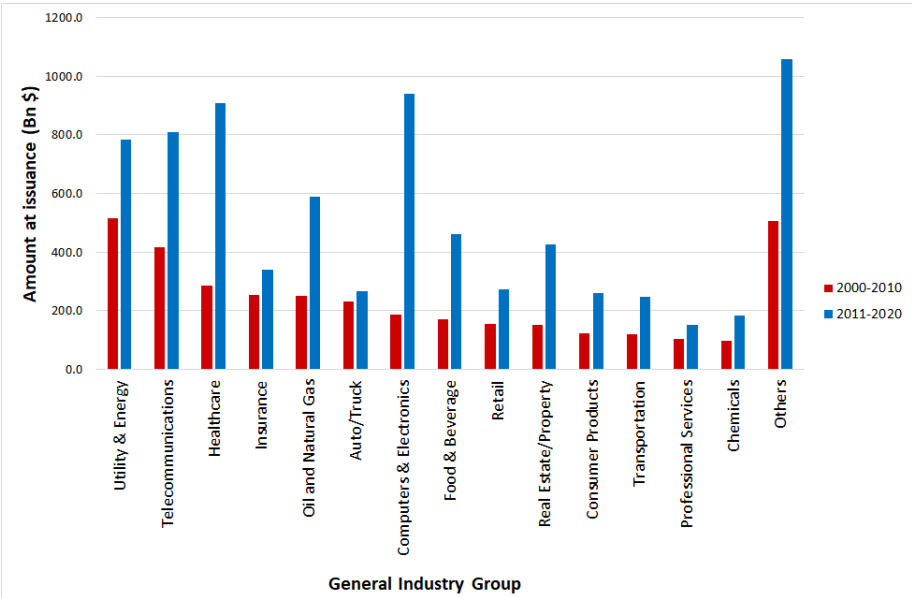

Figure 1: US Non-financial corporations bond issuances in 2000-2010 and 2011-2020. Source: Dealogic DCM

Figure 2 reports the weighted rating at sector level. The Oil and Natural Gas sector was the less creditworthy in the first period (2000-2010) with a rating averaging at 9.1, which decreases to 8.6 in the second period (2011-2020). [6] By looking at figure 1 and 2 the Oil and Natural Gas sector should be strictly monitored given the large amount of debt issued and its low level of

[5]The sector *others* collects the following general industry groups: Professional Services, Chemicals, Leisure & Recreation,Construction/Building, Machinery, Forestry & Paper,Aerospace, Dining & Lodging, Metal & Steel, Publishing, Mining, Holding Companies, Defense, Textile,Closed End Funds, and Agribusiness.

[6]The rating score is defined as the weighted average of companies' rating, with weights being the amount at issuance. The rating is computed by considering the most important credit agencies (Standard & Poor, Moody's and Fitch. The rating score of investments bonds varies from 1 to 10. The maximum creditworthiness is defined by 1, the lowest grade, just before the *junk bonds* by 10.

creditworthiness. The monitoring should not be confined to the evaluation of single companies or of the sector overall risk. On the contrary, a systemic evaluation should also be considered, in order to determine how potential risks that originate in the oil and gas sector could spread in the entire financial system affecting its stability. We pursue this line of research first introducing the methodology and then focusing on the empirical evidence we find.

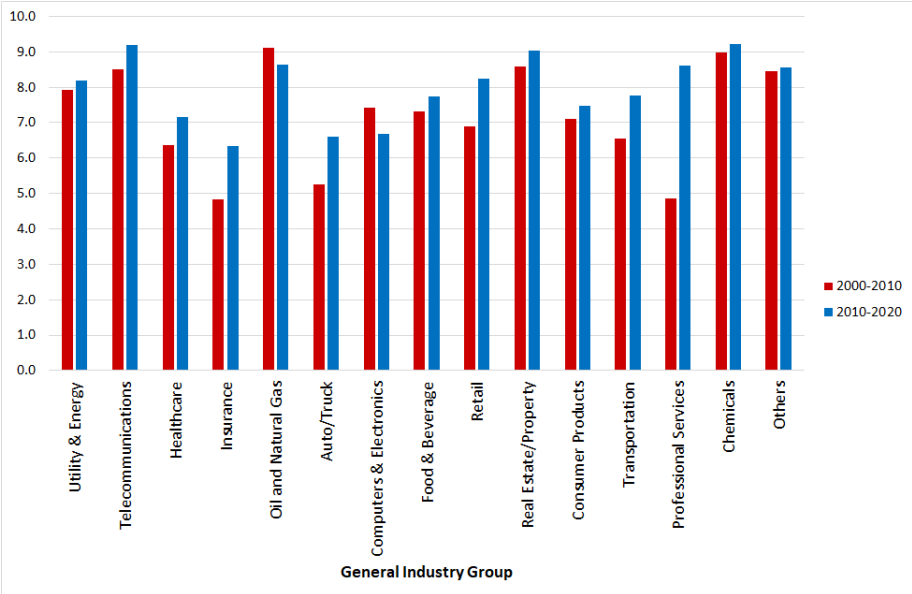

Figure 2: US Non-financial corporations rating in 2000-2010 and 2011-2020.Source: Dealogic DCM

3 Methodology

The econometric literature includes several different methodologies that might be considered for the purpose of monitoring the systemic riskiness of a sector by looking at market data. In this vein, Adrian and Brunnermeier (2016) introduced the $\Delta - CoVaR$ to evaluate the systemic risk of single companies when they enter into a distress state. From a methodological point of view, the $\Delta - CoVaR$ is estimated with a two-step procedure. Let us denote by X_t^i the losses at time t for company i, where losses are obtained as the negative of stock price returns. Moreover, X_t^{system} is the system loss at time t, and M_t a vector of state variables at time t. The first step in the $\Delta - CoVaR$ estimation is the estimation by means of Quantile Regression (Koenker, 2005) of the two linear models

$$X_t^i = \alpha_q^i + \gamma_q^i M_{t-1} + \epsilon_{q,t}^i \tag{1}$$

$$X_t^{system} = \alpha_q^{system|i} + \gamma_q^{system|i} M_{t-1} + \beta_q^{system|i} X_t + \epsilon_{q,t}^{system|i} \tag{2}$$

where subscripts q identifies the estimated quantile, and the superscripts $system \mid i$ highlights that the coefficients account for the dependence of the system from oil company i. Following a standard practice, for the system we consider the quantiles $q = 0.99$ and $q = 0.95$ i.e., the 1% and 5% upper tails of losses, while the for the company we consider the same quantiles of the system, and we also add the median, i.e., $q = 0.50$.

Given the estimated coefficients, we compute the Value-at-Risk of the company, i.e., $VaR_{q,t}^i$,

$$VaR_{q,t}^i = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1}, \quad q = 0.5, 0.95, 0.99, \tag{3}$$

and the q Conditional-Value-at-Risk of the system when the company i losses are set at their τ quantile, namely $CoVaR_{q,t}^{system|i,\tau}$:

$$\begin{aligned} CoVaR_{q,t}^{system|i,\tau} &= \hat{\alpha}_q^{system|i} + \hat{\gamma}_q^{system|i} M_{t-1} + \hat{\beta}_q^{system|i} VaR_{\tau,t}^i \\ \{q, \tau\} &= \{(0.99, 0.99), (0.95, 0.95), (0.99, 0.50), (0.95, 0.50)\}. \end{aligned} \tag{4}$$

Finally, building on the estimated risk measures, we compute the impact on the system of the distress in the company i. The distress is associated with the company return moving from the median level of losses to an upper quantile of losses. The $\Delta - CoVaR_{q,t}$ equals

$$\Delta CoVaR_{q,t}^{system|i} = (CoVaR_{q,t}^{system|i,q} - CoVaR_{q,t}^{system|i,0.5}) = \hat{\beta}_q^{system|i}(VaR_{q,t}^i - VaR_{0.50,t}^i), \tag{5}$$

with the usual choices for the quantile level, i.e., $q = 0.95$ or $q = 0.99$.

The $\Delta CoVaR_{q,t}^{system|i}$ is expressed in the unit of measure adopted for losses, i.e. percentages but is some circumstances it is more interesting to analyse its monetary value. In this case the risk measure is multiplied by a proxy for of the company size expressed (usually) in US Dollars, leading to $\Delta^{\$} CoVaR_{q,t}^{system|i}$. We report the results of $\Delta^{\$} CoVaR_{q,t}^{system|i}$ in section 7.2. The evaluation of $\Delta CoVaR_{q,t}^{system|i}$ will provide insights on the company-specific systemic risk, and by contrasting this risk measures in a panel of companies over periods we might identify changes in the level and in the dispersion of risk. In addition, further analyses would allow us

to identify possible drivers of the oil and gas companies systemic risk, with the possibility of inferring potential sources of risk that could lead to a deterioration of the sector's systemic risk.

4 Data and preliminary analyses

We downloaded the US Oil and Natural Gas companies stock returns, weekly based, from Refinitiv/Eikon. The sample covers, according to the NACE 4-digit classification, the following economic activities (NACE code in parentheses): Extraction of crude petroleum (06.10), Extraction of natural gas (NACE) (06.20), Support activities for petroleum and natural gas extraction (NACE) (09.10). The time horizon spans from January 2000 to December 2021. Figure 3 compares the number of US listed firms companies in Oil and Natural Gas sectors with the price of Crude Oil-West Texas Intermediate and the price of natural gas (Henry Hub Spot price). Overall, the number of public Oil and Natural Gas companies raised in 2000, dropped after the global financial crisis in 2008 and reached a maximum of 137 in 2018; finally, the number plummeted to 97 at end of 2021. The first drop might be related to the consequences of the global financial crisis; the more recent contraction in active companies is due to the COVID-19 outbreak and its impact on the real economy. The entire sample is thus characterised by two sub-samples including first a phase of moderate increase in the number of companies, a second phase with a more steeper increase in the companies, and then a third phase with a drop.

Beside this evidence, the evolution of the number of companies is also associated with the margin that Oil and Natural Gas firms have beyond the costs of the investment, i.e., it is s function of the price of WTI and of the Henry Hub spot price (the natural gas reference price). Periods where contractions of oil and natural gas prices occurred also registered reductions in the number of firms. By combining the patterns in the number of active companies and the patterns in the oil and gas prices, we decided to analyse separately the sub-samples 2000-2010 and 2011-2021; such a choice is also coherent with the evidence in Caporin et al. (2019) that identity a structural break in the oil price time series, located at the beginning of 2011.

We first proceed to a filtering step on the downloaded stock return series: we consider all the assets that, in the time period considered, are characterized by the presence of non-missing values for at least two years (100 consecutive observations). Such a choice excludes companies active from 2010 to 2010, or from 2011 to 2021, for short period of times and, at the same time, keeps track of all firms that entered or left the market during the time period we consider. Our

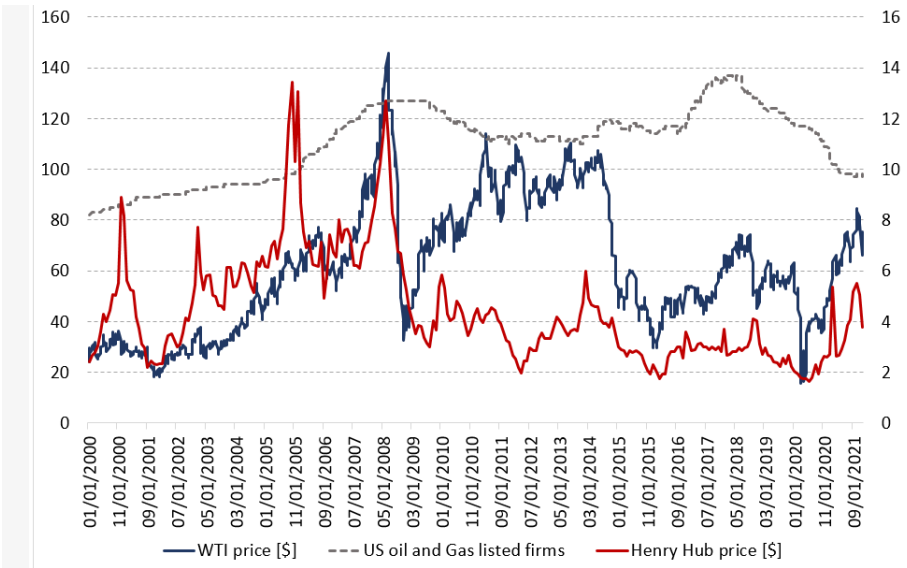

Figure 3: The figure reports on the left y-axis the number of US Oil and Natural Gas firms over time from 2000 to December 2021 (dashed line) and on the red line the price of WTI. The right y-axis shows the Henry Hub Spot price of Natural Gas.

potential sample comprehends 127 listed companies in 2000-2010 and 165 firms in 2011-2021.[7]

Table 1 reports the number of firms by sector (NACE 4-digit code) and period, and some descriptive statistic of their market capitalization. Notably, in the first period, the 57% of the firms belongs to the extraction of crude oil, followed by firms involved in support activities, 27%, and finally by those focused on the extraction of gas, 16%. The composition remains roughly unchanged in the second period, even though we observe an increasing number of firms. In addition, the number of firms belonging to the extraction of natural gas enlarged in favor of extraction of crude oil and support activities. If we focus on the market capitalization, we observe that it is increased in the second period. Firms that belong to the extraction of natural gas are bigger than those being part of the other sectors. Table 1 reports the mean, the standard deviation, the median, the 10% and 90% quantiles of the weekly market capitalization, averaged over time.[8] The high standard deviation and the discrepancy between the average and the mean show evidence of the relevant heterogeneity in the sectors' market value. Firms that belong to the extraction of natural gas, have the highest median in the first period, reaching a value of

[7]The selection criteria we chose is potentially excluding companies that entered the market before 2010, and that are active for less than two years both in the first and in the second sample. However, we note that we do not exclude companies for this reason. In addition, companies entering the market before 2010 active for less than two years in the first sample and for more than two years in the second sample are 73 (the companies are included in the second sample only). Finally, companies entering the market before 2010, active for more than two years in the first sample and for less than two years in the second sample are 35 (these companies are included in the first sample only).

[8]We first average over time the weekly market capitalization of the various companies and then proceed to evaluate the descriptive statistics over the cross-section.

$2125 millions, followed by firms in the supporting activities with a value of $992 millions, and extraction of crude oil firms, $471 millions. If we look at the mean, the ranking of the market value remains unchanged. In the second period, the extraction of crude oil sector increased its dimension, moving to the second highest market cap, with $5087 millions, on average. The extraction of natural gas remains the biggest sector with median capitalization equal to $5132 millions. Notably, focusing on the difference between the mean and median and on the market value dispersion, the extraction of crude oil has and the support activities companies are more heterogeneous that the gas extraction companies.

Table 1: The table reports the number of firms (absolute value and percentage) and the weekly market capitalization averaged across time expressed in millions of dollars (M $). We compute, over the cross-section, the mean, the standard deviation, the median, and the 10% and 90% quantiles.

07-01-2000 31-12-2010							
NACE code 4-digits	**Nfirms**	**%**	**Mean**	**Std**	**Median**	**Q10**	**Q90**
			Market cap [M$]				
Extraction of crude petroleum (NACE) (06.10)	71	56.69	3363	9298	471	49	8381
Extraction of natural gas (NACE) (06.20)	21	16.54	4347	5474	2125	74	14079
Support activities for petroleum and natural gas extraction (NACE) (09.10)	34	26.77	3636	10241	992	73	6735
07-01-2011 31-12-2021							
NACE code 4-digits	**Nfirms**	**%**	**Mean**	**Std**	**Median**	**Q10**	**Q90**
			Market cap [M$]				
Extraction of crude petroleum (NACE) (06.10)	90	54.55	5087	11857	1005	82	15693
Extraction of natural gas (NACE) (06.20)	34	20.61	5132	5496	3711	319	10791
Support activities for petroleum and natural gas extraction (NACE) (09.10)	41	24.85	4304	14224	995	92	5087

To proceed with the analysis, we follow the contribution of Sadorsky (2001) who shows that exchange rates, crude oil prices and interest rates each have large and significant impacts on stock price returns in the Canadian Oil and Natural Gas industry. Therefore, for the systemic risk analysis of the US Oil and Natural Gas companies, we select the following state variables for inclusion in equations (3) and (5). First, we use *Tbill3M*, which is the change in the three-months Treasury Bills rates. This variable measures the attractiveness of the risk free rate in the US economy. Then, we include *Term_spread_10Y3M*, a measure of term-spread, computed as the difference between the 10 years bond yield and the three-months Treasury Bills rate. The term spread measures the slope of the bond yield curve. Further, we include *Credit_spread*, which is the difference between the ICE Bank of America BBB US corporate index and the Treasury 10 years bond yield. The credit spread monitors the additional risk faced by investors when buying

corporate debt in place of a safer government debt. In addition, we introduce Ret_{MKT}, the Standard & Poor's 500 market index return, and Ret_{WTI}, the West Texas Intermediate crude oil price return. The WTI oil grade is also known as Texas light sweet and it is sourced from U.S. oil fields. We also add $Price_{WTI} - Price_{BRE}$, is the difference between the West Texas Intermediate and the European Brent oil prices. The difference measures the disagreement in oil price between the two most predominant world oil benchmarks. To monitor the market stress we introduce Δ *VIX*, the change in the Russell volatility index, defined as the implied volatility of a synthetic at-the-money option of the Russel 2000 index. Finally, to proxy for buying habits of urban consumers we introduce *Inflation rate*, a measure of the average monthly change in the prices for goods and services paid by urban consumers. A detailed description of the variables and their sources are reported in the Appendix, Table 10.

For our analyses, we split the sample in two time-periods: the first spans from 07-01-2000 to 31-12-2010, the second one from 07-01-2011 to 31-12-2021. As we already mentioned, this is in coherence with Caporin et al. (2019) who found a structural break located in early 2011 by studying the long-run relationship in the WTI-Brent oil time series; the break was due to the rise of shale oil production.[9] Such a choice allows us to identify possible changes in the systemic risk of Oil and Natural Gas companies by contrasting the first part of our data, characterised by the development of the shale oil sector, with the second decade, where the US boosted shale oil production, becoming a leader in oil supply.

Table 2 reports the descriptive analysis of the state variables in the two time periods. Except for *Tbill3M*, that is approaching zero, moving from $-9.1\times^{-5}$ in the first period to -1.3×10^{-6} in the second period, *Term_spread_10Y3M*, *Ted_spread* and *Credit_spread*, on average, registered a contraction in the second period. By contrast, Ret_{MKT} (0.0001 to 0.0027) increased. Besides, Ret_{WTI} shrinks its average value from, 0.0022 to -0.0003, while Δ *VIX* and $Price_{WTI} - Price_{BRE}$ have increased their average reaching a value of -0.0009 and 0.0849 during the second period, compared to -0.0120 and -0.0373, respectively, in the first period. The Inflation rate drops form 0.0903 to 0.0722 when contrasting the first and the second periods. All variables are leptokurtic except for *Term_spread_10Y3M*.

[9]Caporin et al. (2019) identify a break at the beginning of the month of February 2011. However, given the analyses we plan to develop in the following sections, we set the break at the end of 2010. This is helping in moving the data frequency to the quarterly level; see Section 5.

Table 2: The table shows the descriptive statistics of state variables weekly based. Firstly we average the time series, weekly based, across time and then we compute the distribution. The table reports the mean, the standard deviation, the skewness, the kurtosis, the minimum and the maximum value of the state variable distribution.

	07-01-2000 to 31-12-2010					
	Mean	**Std**	**Kurtosis**	**Skewness**	**Min**	**Max**
Tbill3M	-9.1E-05	0.0013	17.524	-1.200	-0.0080	0.0083
Term_spread_10Y3M	0.0012	0.0179	2.194	-0.378	-0.0296	0.0318
Ted_spread	0.0053	0.0051	15.666	2.950	0.0010	0.0425
Credit_spread	0.0200	0.0122	8.874	2.263	0.0063	0.0722
Ret_{MKT}	0.0001	0.0275	9.764	-0.849	-0.2002	0.1141
Ret_WTI	0.0022	0.0573	7.993	-0.369	-0.3122	0.3594
$Price_{WTI}$-$Price_{BRE}$	-0.0373	0.0475	4.408	0.202	-0.2022	0.1733
ΔVIX	-0.0120	3.2334	14.585	0.654	-19.2400	24.8100
Inflation rate	0.0903	0.1620	10.988	-1.418	-0.7684	0.6750
	07-01-2011 to 31-12-2021					
	Mean	**Std**	**Kurtosis**	**Skewness**	**Min**	**Max**
Tbill3M	-1.3E-06	0.0005	135.756	-8.003	-0.0087	0.0022
Term_spread_10Y3M	0.0004	0.0080	2.245	-0.160	-0.0167	0.0188
Ted_spread	0.0028	0.0015	15.777	2.438	0.0003	0.0146
Credit_spread	0.0156	0.0048	7.560	1.476	0.0084	0.0455
Ret_{MKT}	0.0027	0.0222	12.015	-1.052	-0.1620	0.1146
Ret_WTI	-0.0003	0.0601	26.183	0.666	-0.3689	0.6028
$Price_{WTI}$-$Price_{BRE}$	0.0849	0.0668	4.423	0.495	-0.2153	0.3671
ΔVIX	-0.0009	3.4249	10.685	0.652	-18.7400	23.0300
Inflation rate	0.0722	0.1215	7.831	-1.206	-0.5128	0.3320

Table 3 reports the summary statistics for the market equity losses X_t^i and for the risk measures of the Oil and Natural Gas firms in the two periods we consider. We first average the time series for each firm and then we calculate, cross-sectionally, the mean, the standard deviation, the median, the 10% and 90% quantiles. Both $VaR_{q,t}^i$ and $\Delta CoVaR_{q,t}^i$ are obtained by running the quantile regressions in equations 3, 5 and 5, at quantiles 0.99 and 0.95. We also report $VaR_{q,t}^{Sys}$, the financial system Value-at-Risk, again at quantiles 0.99 and 0.95. The last two columns exhibit the number of firms used in the corresponding period and the number of weeks in the period, respectively.

In the first period $(2000 - 2010)$ the Oil and Natural Gas firms registered negative losses (gains) equals in average to -0.002 (-2.9% if we consider the annualized average in percentage). At the contrary, in the second period $(2011 - 2021)$ the losses rise to 0.003 (3.8% if we consider the annualized average in percentage). On average, Var_{95}^i at firm level equals 0.124 roughly comparable with the Var_{95}^i at the second period 0.130. Besides, Var_{99}^i soars from 0.218 to 0.228. The effects is more pronounced when we focus on the median, both the VaR_{99}^i and

VaR^i_{95} increased over time from 0.183 to 0.200 and from 0.113 to 0.121 respectively. The $\Delta CoVaR_{95}$ is unchanged across two periods (0.018 vs 0.013). The same considerations can be applied to the results at quantile equal to 0.99 (0.033 vs 0.025). Finally, if we focus on the market capitalization, the firms increased decisively their magnitude across two periods,from \$3599 millions to \$4901 millions, on average.[10]

5 ΔCoVaR and its predictors over time

In this section we investigate the drivers affecting the cross-sectional dispersion of the $\Delta - CoVaR$ in the two periods under study. In the same fashion of (Adrian and Brunnermeier, 2016), we use as predictors the state variables and some institution characteristics. This larger set of risk predictors has a crucial role: systemic risk arises in normal times and thus predictors can act as early-warning indicators. Since the firm characteristics and further potentially relevant state control variables have lower frequency, borrowing from (Adrian and Brunnermeier, 2016), we aggregate $\Delta - CoVaR$ at the quarterly level. Specifically, starting from weekly $\Delta CoVaR^{system|i}_{q,t}$ we generate a weekly panel of $\Delta^{\$}CoVaR^{system|i}_{q,t}$ by multiplying each company-specific risk measure by the market capitalization of the conditioning institution i at time t and then we normalise it by the cross-sectional average of market equity at time t. Finally, we obtain quarterly figures of $\Delta CoVaR^{system|i}_{q,t}$ by averaging over the weekly observations within each quarter.

$\Delta CoVaR^{system|i}_{q,t}$ becomes our dependent variable, which is then regressed over lagged state variables, M_{t-1}, and lagged firm characteristics, X_{t-1}. Note that the predictors are all lagged by a single quarter. The specification we adopt is the following:

$$\Delta CoVaR^{system|i}_{q,t} = a + cM_{t-1} + bX_{t-1} + \eta_t \tag{6}$$

The state variables and the firm controls that we include in this regression are summarized in table 10. The firms characteristics we take into account are the following:

- $VaR_{q,QPYYYY-QPYYYY}$: the time series of quarterly losses at the $q\%$ quantile, obtained by averaging the weekly observation within the quarter. The weekly VaR is estimated by using (3). The time horizon is defined by the quarter QP=Q1,...,Q4 and the year YYYY;
- *Size*: computed as the logarithm of the market capitalization;

[10]For what concerns state variables, we do not comment on their role on the evaluation of the risk indicators at both the company and the market level. They are included to account for the overall economy state.

Table 3: The table reports the summary statistics of the market equity losses $X_t^i$and the systemic risk measures $VaR_{q,t}^i$, $\Delta CoVaR_{q,t}^i$ and the financial system value at risk $VaR_{q,t}^{Sys}$ at quantile 99 and 95 percent. Firstly we average the weekly time series across time and then we compute the distribution.

07-01-2000 31-12-2010													
	Mean	**Std**	**Median**	**Q10**	**Q90**		**Mean**	**Std**	**Median**	**Q10**	**Q90**	**# firms**	**Obs**
X_t^i	-0.002	0.004	-0.003	-0.006	0.003	X_t^i	-0.002	0.004	-0.003	-0.006	0.003	127	573
$VaR_{99,t}^i$	0.218	0.120	0.183	0.113	0.351	$VaR_{95,t}^i$	0.124	0.057	0.113	0.073	0.174	127	573
$\Delta CoVaR_{99,t}$	0.033	0.017	0.035	0.011	0.053	$\Delta CoVaR_{95,t}$	0.018	0.009	0.019	0.005	0.028	127	573
$VaR_{99,t}^{Sys}$	0.067	0.009	0.068	0.055	0.080	$VaR_{95,t}^{Sys}$	0.039	0.005	0.039	0.034	0.045	127	573
Market Cap (M$)	3599	9003	654	56	8411	Market Cap (M$)	3599	9003	654	56	8411	127	574
07-01-2011 31-12-2021													
	Mean	**Std**	**Median**	**Q10**	**Q90**		**Mean**	**Std**	**Median**	**Q10**	**Q90**	**# firms**	**Obs**
X_t^i	0.003	0.007	0.002	-0.002	0.012	X_t^i	0.003	0.007	0.002	-0.002	0.012	165	573
$VaR_{99,t}^i$	0.228	0.122	0.200	0.129	0.358	$VaR_{95,t}^i$	0.130	0.049	0.121	0.078	0.185	165	573
$\Delta CoVaR_{99,t}$	0.025	0.014	0.025	0.008	0.039	$\Delta CoVaR_{95,t}$	0.013	0.006	0.013	0.005	0.021	165	573
$VaR_{99,t}^{Sys}$	0.051	0.008	0.051	0.040	0.061	$VaR_{95,t}^{Sys}$	0.030	0.004	0.030	0.025	0.037	165	573
Market Cap (M$)	4901	11480	1081	107	14396	Market Cap (M$)	4901	11480	1081	107	14396	164	574

- *Debt*:computed as the logarithm of the total debt;
- *ROA*: the ratio between *operating income* and *total asset income*;
- *ROE*: the ratio between *operating income* and *common equity*;
- $\Delta NRIG_{\%}$: the percentage variation in the number of active oil rigs.

We also define two alternative specifications of in equation 6 by interacting the *VaR* with *Size* as equation 7 and interacting *VaR* with $Size^2$ as in equation 8.

$$\Delta CoVaR_{q,t}^{system|i} = a + b_1 VaR_{q,t-1} + b_2 Size_{t-1} + b_3 VaR_{q,t-1} \times Size_{t-1} + \mathbf{b}'_X \mathbf{X}_{t-1} + \mathbf{c}'_M \mathbf{M}_{t-1} + \eta_t \tag{7}$$

$$\begin{aligned}\Delta CoVaR_{q,t}^{system|i} &= a + b_1 VaR_{q,t-1} + b_2 Size_{t-1} + b_3 Size_{t-1}^2 + \\ &+ b_4 VaR_{q,t-1} \times Size_{t-1} + b_5 VaR_{q,t-1} \times Size_{t-1}^2 + \mathbf{b}'_X \mathbf{X}_{t-1} + \mathbf{c}'_M \mathbf{M}_{t-1} + \eta_t \end{aligned} \tag{8}$$

The two alternative specifications are crucial to spot some non-linearity that could affect the dependent variable. Table 4 reports the summary statistics of $\Delta CoVaR$ and VaR at 0.99 and 0.95 quantiles, and of the firm characteristics. We focus on the two periods, $Q12000 - Q42010$ and $Q12011 - Q42021$, in order to identify the the impact of the oil and gas sector structural and technological changes in the relation between predictors and systemic risk measures.

The average value of $\Delta CoVaR$ at 95% and 99% remain constant from the first period values, 0.018 and 0.034, to 0.014 and 0.025 in the second period. The same considerations hold for $\Delta CoVaR^{\$}$ at 95% and 99%. The average of VaR at 95% and 99%, slightly soar from 0.120 and 0.213 in the first period to 0.129 and 0.225 in the second period, the effect is stronger if we consider the median. *Tbill3M* is bounded to zero across the two periods *Ted_spread* moved from 0.005 in Q1 2000 - Q4 2010 to 0.003 in Q4 2011 - Q4 2021. In the same fashion, *Credit_spread* reduces to 0.016 in the second period, from the first period value of 0.02. The Oil and Natural Gas industry portfolio (*Oil*) remains constant across the two periods to 0.005. Q1 2010 - Q4 2021 has lower inflation rate compared to the second period, decreasing from 1.16 to 1.33. Ret_{WTI} reduced the average from 0.03 to -0.04 and -0.021 instead $Ret_{HenryHub}$ spurred its value to 0.005. If we focus on firm's variables, *Size* remains constant to 20 across the two periods instead the average of *Debt* is increased in the second period to 11.7 from 10.4. *ROA* raises to 0.136 to

the second periods showing a opposite behaviour with respect to *ROE* that sinks to 1.4 and reminding how much it is important to use both firms' profitability indicators. *ROE*'s median is far away from the mean in both periods due to the presence of extreme observations. In any case, *ROE* value plummeted during the second period from 5.05 to 1.4. If we look at the median, *ROE* reduces its value from 0.20 to 0.09. The number of rigs percentage changes $\Delta NRIGS_{\%}$ slumps in the second period to -0.017. Overall, a preliminary evaluation of the data features in the two samples highlights the presence of some differences, linked to the changes in the oil and natural gas production, with the increased shale oil production, but also due to the variation in the financial system risk dominated in the first period by the global financial crisis while the end of the second period suffers for the effect of the first wave of the Covid-19 pandemic.

6 The drivers of systemic risk in Oil and Natural Gas companies

Table 5 reports the panel regression results for two time windows, Q1 2000 - Q4 2010, Q1 2011 - Q4 2021.[11] We stress that all the drivers are lagged by one quarter, coherently with equation 6. As we are dealing with panel estimates, we control for the time invariant heterogeneity by resorting to a fixed effect estimator. The standard errors are clustered by firm. Table 5 panel A shows that the VaR at 99% and 95% levels have lower impact on *Delta* CoVaR in Q1 2000 - Q4 2010 than Q1 2011 - Q2 2021. If we focus on Q1 2011 - Q4 2021, VaR at 99%, on average, affects Δ CoVaR with a magnitude equal to 4.9%; the effect is equal to 4.2% and slightly higher than the first period when we consider the 95% VaR.

Ted_spread, *Credit_spread* and *Inflation rate* have a positive and significant impact on the Δ CoVaR in all periods. *Tbill3M* is negative and significant for Δ CoVaR at 95% and 99% but only in Q1 2011 - Q4 2021, with coefficients roughly equal to -0.44 in both cases. The impact of the Oil and Natural Gas sector (*Oil*) changes across two periods: in the first period has a positive effect on Δ CoVaR but the effect is lower and negative in the second period. Ret_{WTI} and $Ret_{HenryHub}$ have a negative and significant impact on Δ CoVaR at 95% and 99%, particularly $Ret_{HenryHub}$ is significant in all periods while Ret_{WTI} is relevant only in the second period.

When we consider the firm characteristic, *Size* has a slight positive impact on Δ-CoVaR at 99% in the second period. *ROE* has a oscillating impact: the sign of*ROE* changes at different

[11]The table shows only the coefficients for the variables of interest. The complete regressions with the control variables coefficients are included in the Appendix; see Table 11, Table 12, and Table 13, respectively.

Table 4: The table reports for each variable and the descriptive statistics in two sub-periods: From January 2000 to December 2010 reported in panel A, and from January 2011 to December 2021 reported in panel B. Data are quarterly based. The descriptive statistics comprehend the mean, the standard deviation, the skewness, the kurtosis, the quantile at 25 %, the median, the quantile at 75 % , the minimum and the maximum value of the state variable distribution.

Panel A					**Q12000-Q42010**					
VARIABLES	**N**	**mean**	**sd**	**skewness**	**kurtosis**	**p25**	**p50**	**p75**	**min**	**max**
$\Delta CoVaR99$	4,470	0.034	0.024	2.034	11.130	0.019	0.030	0.044	0.000	0.276
$\Delta CoVaR95$	4,472	0.018	0.012	1.867	9.119	0.009	0.016	0.023	0.000	0.106
$\Delta CoVaR^{\$}99$	4,470	0.041	0.125	10.960	203.100	0.001	0.005	0.028	0.000	3.478
$\Delta CoVaR^{\$}95$	4,472	0.025	0.079	8.645	111.900	0.000	0.003	0.016	0.000	1.641
var99	4,529	0.213	0.160	3.463	25.920	0.118	0.168	0.255	0.019	2.544
var95	4,529	0.120	0.077	2.563	14.470	0.072	0.099	0.142	0.005	0.959
Tbill3M	9,416	-0.001	0.005	-1.119	3.658	-0.002	0.000	0.002	-0.014	0.006
Ted_spread	9,416	0.005	0.005	2.128	8.150	0.002	0.004	0.006	0.002	0.025
Credit_spread	9,416	0.020	0.012	2.146	8.116	0.013	0.017	0.024	0.007	0.063
Oil	9,416	0.006	0.022	2.237	10.970	-0.005	0.002	0.012	-0.031	0.106
Ret_WTI	9,416	0.029	0.187	-1.947	10.330	-0.031	0.052	0.121	-0.814	0.342
Inflation Rate	9,416	1.165	1.322	-2.379	11.750	0.833	1.349	1.835	-5.012	3.323
Henry Hub_ret	9,416	0.010	0.224	-0.243	2.282	-0.155	0.041	0.190	-0.465	0.391
size	4,675	20.090	2.291	-0.195	2.719	18.460	20.230	21.700	11.780	25.690
debt	4,428	10.430	4.746	-1.232	3.411	9.089	12.050	13.650	0.000	17.170
ROA	4,432	0.055	3.048	-36.400	1376.000	0.038	0.089	0.148	-115.000	7.724
ROE	4,432	5.051	55.820	13.070	195.400	0.077	0.203	0.331	-300.000	976.300
$\Delta NRIGS_{\%}$	9,416	0.010	0.119	-1.379	4.960	-0.028	0.035	0.083	-0.368	0.184
Panel B					**Q12011-Q42021**					
VARIABLES	**N**	**mean**	**sd**	**skewness**	**kurtosis**	**p25**	**p50**	**p75**	**min**	**max**
$\Delta CoVaR99$	4,853	0.025	0.014	1.439	10.630	0.016	0.025	0.033	0.000	0.162
$\Delta CoVaR95$	4,840	0.014	0.007	0.793	4.799	0.009	0.014	0.018	0.001	0.059
$\Delta CoVaR^{\$}99$	4,845	0.034	0.075	3.704	19.610	0.001	0.006	0.024	0.000	0.730
$\Delta CoVaR^{\$}95$	4,832	0.022	0.053	4.215	24.660	0.001	0.003	0.014	0.000	0.557
var99	4,991	0.225	0.124	3.739	38.970	0.149	0.197	0.272	0.033	2.428
var95	4,991	0.129	0.059	1.949	13.390	0.089	0.117	0.156	0.018	0.833
Tbill3M	9,416	0.000	0.002	-2.317	11.380	0.000	0.000	0.001	-0.010	0.004
Ted_spread	9,416	0.003	0.001	0.402	2.237	0.002	0.003	0.004	0.001	0.005
Credit_spread	9,416	0.016	0.004	0.634	2.951	0.012	0.015	0.018	0.009	0.027
Oil	9,416	0.005	0.024	-0.371	3.405	-0.011	0.007	0.022	-0.066	0.053
Ret_WTI	9,416	-0.004	0.256	-1.639	9.285	-0.085	0.026	0.127	-1.093	0.651
Inflation Rate	9,416	1.334	1.385	0.611	5.097	0.848	1.253	1.803	-2.200	5.250
Henry Hub_ret	9,416	0.005	0.171	0.299	2.567	-0.115	-0.003	0.094	-0.307	0.394
size	5,131	20.660	2.190	-0.227	2.605	19.240	20.760	22.220	12.770	25.750
debt	4,501	11.710	4.670	-1.598	4.522	10.860	13.350	14.660	0.000	17.470
ROA	4,545	0.136	1.946	30.600	993.800	-0.017	0.043	0.095	-2.123	63.570
ROE	4,545	1.484	18.020	17.940	374.100	-0.030	0.096	0.231	-6.340	438.500
$\Delta NRIGS_{\%}$	9,416	-0.017	0.216	-1.519	5.638	-0.046	0.021	0.110	-0.779	0.328

quantile levels. Finally $\Delta NRIGS_{\%}$ negatively affects Δ CoVaR at 95% and 99% but only in the first period. Interestingly, a positive trend of $\Delta NRIGS_{\%}$ measures in which extent the oil business is active in US. Increasing number of rigs state that the sector is still expanding and therefore the cash flow of that activity rewards the shareholders and consequently it reduces the systemic risk associated to that business.

The relation between company size and the company systemic risk might be, however, non-linear. To dig into that direction, we report in Panel B the coefficients when we interact VaR with *Size* and with $Size^2$. The interaction term is positive and significant while instead the two variables alone, VaR and *Size*, have a negative and significant impact to $\Delta CoVaR$. However, the overall impact is difficult to identify by simply looking at estimated coefficients. The specifications in Panel B and Panel C are important to understand in which extent the VaR coefficient changes with respect to the size of the firms. Figure 4 shows the overall effect due to the interaction between VaR and *size* for different levels of *Size*; the figure reports the estimated value (red lines) and the 95% confidence interval (blue dashed lines) of $b_1 + b_3 Size_{t-1}$. The left side of the figure, plots (a) and (c), report the coefficient for the first period: the joint impact is not significant when VaR is at 99%, but the effect is significant in the case of quantile at 95% and the company size is greater than M$17.9. In the second period, the overall impact is smaller, but it is significant at 99% and at 95% when the company size goes above of M$2.4 and M$12.0, respectively.

Panel C reports the regression results when we decide to interact VaR with $Size$ and $Size^2$. As in the previous case, we compute the composite impact (bow equal to $b_1 + b_4 Size_{t-1} + b_4 Size^2_{t-1}$) and the 95% confidence interval, see figure 5. The left side shows the pattern for the first sample, 2000-2010. The effect is non-significant only for the smallest firm included in the sample, and this holds for both VaR cases, i.e., for the 99% and 95% VaR. In this respect, the coefficient is positive and significant only for firms with a size above than M$884 (a) and M$14.7 (c). The right part of the figure reports the joint impact in 2011-2021. The effect is significant for those firms having $Size$ greater than M$2.1 and at quantile at 99% (b). Differently, in plot (c), the effect is positive and significant after a threshold level of M$9.82. All in all, the graphs show that $Size$ plays a relevant role for VaR but only for big size firms in the first period, while in the second period the threshold separating companies in terms of their reaction to VaR movements is significantly lower in the second period, for both quantiles 95% and 99%.

Table 5: The table reports the results of the fixed effect panel regression relative to the all sample. Panel A shows the coefficients of interest defined by equation 6. Panel B reports the coefficients of interest defined by equation 7 by introducing the interaction between *VaR* and *Size*. Panel C exhibits the coefficients of interest as in equation 8 by interacting *VaR* and $Size^2$. The control variables parameters are respectively in table 11, 12 and 13. Standard errors clustered by firm are in parentheses. *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021
Panel A		Equation6 : Baseline		
$VaR_{99,QPYYYY-QPYYYY}$	0.0253*		0.0494***	
	(0.014)		(0.006)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0405***		0.0422***
		(0.011)		(0.004)
Size	-0.0004	-0.0000	0.0004*	0.0001
	(0.000)	(0.000)	(0.000)	(0.000)
Controls and Constant	YES	YES	YES	YES
Observations	3,580	3,540	3,320	3,325
Number of firms	105	104	123	123
R2	0.565	0.605	0.362	0.378
Adj R2	0.563	0.603	0.360	0.375
Panel B		Equation7 : Baseline + Var*Size		
$VaR_{99,QPYYYY-QPYYYY}$	-0.1577***		-0.0558*	
	(0.055)		(0.029)	
$VaR_{99,QPYYYY-QPYYYY}$ *Size	0.0100***		0.0053***	
	(0.004)		(0.002)	
$VaR_{95,QPYYYY-QPYYYY}$		-0.2879***		-0.1073***
		(0.028)		(0.026)
$VaR_{95,QPYYYY-QPYYYY}$ *Size		0.0184***		0.0075***
		(0.002)		(0.001)
Size	-0.0036***	-0.0029***	-0.0010**	-0.0010***
	(0.001)	(0.000)	(0.000)	(0.000)
Controls and Constant	YES	YES	YES	YES
Observations	3,580	3,540	3,320	3,325
Number of firms	105	104	123	123
R2	0.590	0.675	0.371	0.397
Adj R2	0.588	0.674	0.368	0.394
Panel C		Equation8 : Baseline + Var*Size +Baseline + Var*$Size^2$		
$VaR_{99,QPYYYY-QPYYYY}$	0.3465**		0.1532	
	(0.135)		(0.161)	
$VaR_{99,QPYYYY-QPYYYY}$ *Size	-0.0479***		-0.0165	
	(0.015)		(0.016)	
$VaR_{99,QPYYYY-QPYYYY}$ *$Size^2$	0.0016***		0.0006	
	(0.000)		(0.000)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0127		0.1077
		(0.120)		(0.159)
$VaR_{95,QPYYYY-QPYYYY}$ *Size		-0.0156		-0.0144
		(0.013)		(0.016)
$VaR_{95,QPYYYY-QPYYYY}$ *$Size^2$		0.0010***		0.0006
		(0.000)		(0.000)
Size	-0.0067	-0.0102***	0.0011	0.0009
	(0.006)	(0.002)	(0.004)	(0.002)
$Size^2$	0.0001	0.0002***	-0.0001	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
Controls and Constant	YES	YES	YES	YES
Observations	3,580	3,540	3,320	3,325
Number of firms	105	104	123	123
R2	0.611	0.695	0.372	0.398
Adj R2	0.609	0.694	0.369	0.395

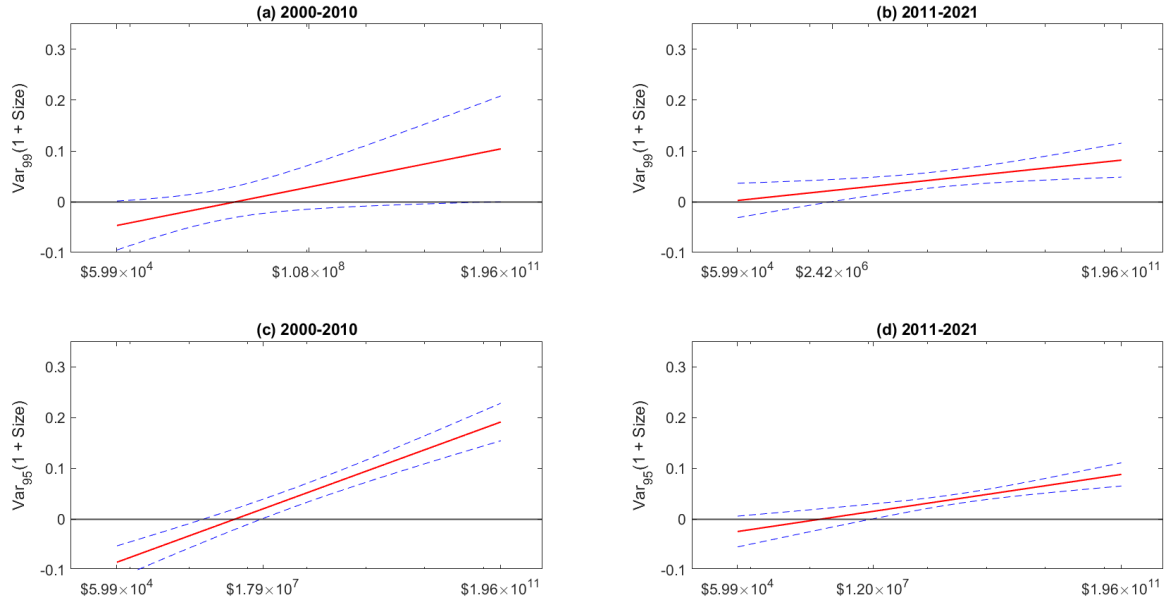

Figure 4: The figure shows the pattern of the joint coefficient $VaR + VaR \times Size$ (red line) with respect to $Size$. The blue dashed lines represent the confidence interval at 99%.

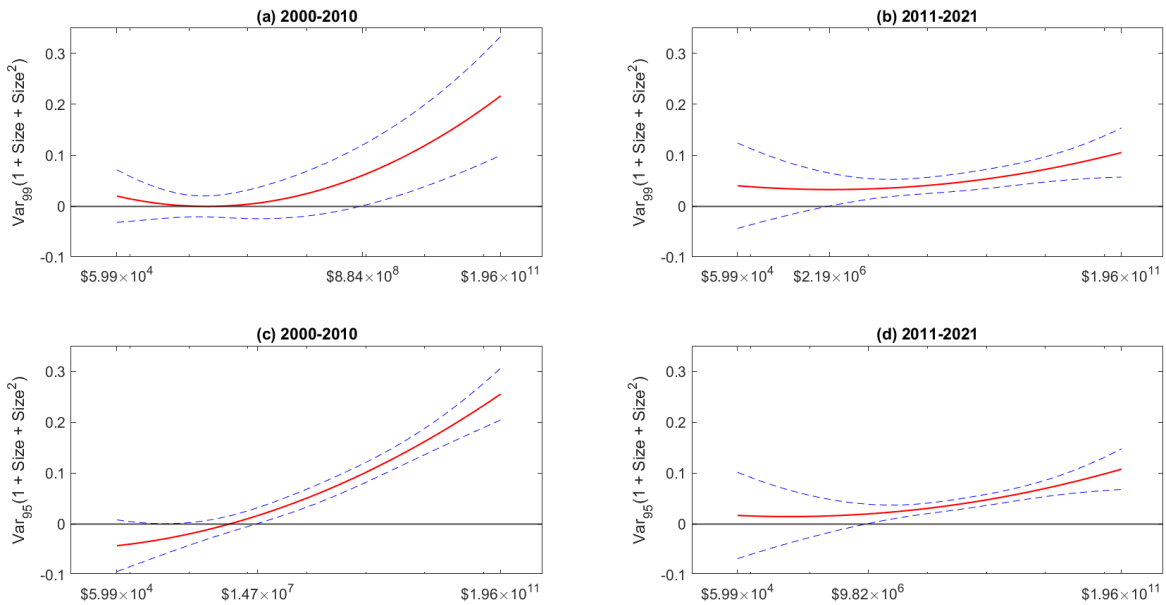

Figure 5: The figure shows the pattern of the joint coefficient $VaR + VaR \times Size + VaR \times Size^2$ (red line) with respect to $Size$. The blue dashed lines represent the confidence interval at 99%.

7 Robustness Checks

7.1 Oil,Gas and Supporting activities

Since the firms in our sample belong to different sub-groups as noted in Table 1, in this section we investigate in which way the effect on $\Delta CoVaR$ change with respect to the inclusion in sub-groups. The extraction of crude oil sector is the largest group, followed by support activities and extraction of natural gas.

Panel A of table 6 shows the regression coefficients when we consider only firms in extraction of crude oil subgroup. The results indicate that the VaR has a significant and stronger impact on $\Delta CoVaR$ in the second period when we consider extreme events (quantile at 99%). The effects is the opposite when we consider the VaR at 95%. In both periods the coefficients are significant. Panel B and C shows the regression coefficient for those firms belonging to the extraction of natural gas and support activities, respectively. In both cases, the VaR is economically and statistically significant only in the second period, showing that these firms are sensibly more risky than the first period. Particularly, the VaR at quantile 99% has the highest magnitude across time and subgroup with a value of 0.07.

7.2 $\Delta CoVaR^{\$}$

In this section we consider the effect of VaR on the $\Delta CoVaR^{\$}$ computed as (Adrian and Brunnermeier, 2016). The difference with equation 6 is that the risk measure is multiplied by a proxy for of the company size expressed (usually) in US Dollars, leading to $\Delta^{\$}CoVaR_{q,t}^{system|i}$. Therefore, the dependent variable is weighted by the firms size. The empirical findings in table 7 reports a sharp difference in terms of VaR impact on $\Delta CoVaR^{\$}$ across two periods. The results corroborate our finding in Table 5. The risk metric is not significant in 2000-2010, the coefficient is positive and significant equals to 0.05 and 0.07, when we look at VaR at 99% and 95%, respectively.

7.3 Balanced panel

We replicate our analysis by making the panel more balanced. We test two alternative specifications: firstly, the *Balanced case*, we choose the listed firms that, in the time period considered, are characterized by the presence of missing values lower than 20% of the time. In this case, we consider firms having available observations more than 80% of the time horizon. The second

Table 6: The table reports the results of the fixed effect panel regression. Panel A in particular frames the analysis for those firms belonging to the Extraction of crude petroleum,(NACE 06.20). Panel B reports the results Extraction of natural gas firms,(NACE 06.20). Finally,Panel C reports for those firms operating as support on the Oil and Natural Gas extraction(NACE 06.20).

Panel A	Extraction of Oil			
VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021
$VaR_{99,QPYYYY-QPYYYY}$	0.0318*		0.0467***	
	(0.016)		(0.009)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0446***		0.0329***
		(0.013)		(0.005)
Size	-0.0006	0.0001	0.0002	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
Controls and Constant	YES	YES	YES	YES
Observations	1,961	1,961	1,872	1,877
Number of firms	57	57	67	67
R2	0.549	0.567	0.322	0.357
Adj R2	0.546	0.564	0.317	0.352
Panel B	Extraction of natural gas			
VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021
$VaR_{99,QPYYYY-QPYYYY}$	0.0105		0.0719***	
	(0.018)		(0.005)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0191		0.0571***
		(0.024)		(0.006)
Size	-0.0008	0.0000	0.0008	0.0004
	(0.001)	(0.000)	(0.001)	(0.000)
Controls and Constant	YES	YES	YES	YES
Observations	526	526	546	546
Number of firms	16	16	23	23
R2	0.666	0.647	0.403	0.349
Adj R2	0.658	0.638	0.389	0.333
Panel C	Support activities			
VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021
$VaR_{99,QPYYYY-QPYYYY}$	0.0121		0.0401***	
	(0.024)		(0.007)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0375		0.0532***
		(0.028)		(0.008)
Size	0.0006	0.0000	0.0008**	0.0004*
	(0.001)	(0.000)	(0.000)	(0.000)
Controls and Constant	YES	YES	YES	YES
Observations	1,093	1,053	902	902
Number of firms	32	31	33	33
R2	0.586	0.677	0.473	0.464
Adj R2	0.581	0.673	0.465	0.456

Table 7: The table reports all the coefficients of the fixed effect panel regression. The dependent variable in equation (6) is computed using the methodology of Adrian and Brunnermeier (2016), where $\Delta CoVaR$ is multiplied by a proxy for of the company size expressed (usually) in US Dollars. Standard errors clustered by firm in parentheses *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	$\Delta_CoVaR99^{\$}$ Q12000-Q42010	$\Delta_CoVaR95^{\$}$ Q12000-Q42010	$\Delta_CoVaR99^{\$}$ Q12011-Q42021	$\Delta_CoVaR95^{\$}$ Q12011-Q42021
$VaR_{99,QPYYYY-QPYYYY}$	-0.0187		0.0504**	
	(0.026)		(0.023)	
$VaR_{95,QPYYYY-QPYYYY}$		-0.0078		0.0692**
		(0.034)		(0.026)
Ted_spread	1.8695**	1.2029**	1.3127*	0.5011
	(0.921)	(0.516)	(0.744)	(0.452)
Credit_spread	0.9207***	0.5070***	0.4093	0.2853
	(0.309)	(0.182)	(0.299)	(0.190)
Tbill3M	-0.4173***	-0.2176***	-0.5097	-0.5745
	(0.115)	(0.079)	(0.545)	(0.437)
Oil sector return	0.3370***	0.1992***	-0.0307*	-0.0257**
	(0.104)	(0.058)	(0.017)	(0.011)
Inflation rate	0.0031*	0.0020**	0.0026***	0.0020***
	(0.002)	(0.001)	(0.001)	(0.001)
Size	0.0107***	0.0063***	0.0114***	0.0072***
	(0.004)	(0.002)	(0.003)	(0.002)
Debt	-0.0007	-0.0005	0.0000	-0.0000
	(0.001)	(0.000)	(0.000)	(0.000)
ROA	-0.3388	-0.2073	-0.2948	0.0420
	(0.356)	(0.222)	(0.459)	(0.246)
ROE	-0.0011	-0.0007	-0.0229	-0.0030***
	(0.001)	(0.000)	(0.026)	(0.001)
RET_{WTI}	-0.0015	-0.0002	-0.0084***	-0.0039**
	(0.003)	(0.002)	(0.003)	(0.002)
$RET_{HenryHub}$	-0.0083	-0.0047	-0.0042	-0.0046**
	(0.006)	(0.003)	(0.003)	(0.002)
$\Delta NRIGS_{\%}$	0.0182***	0.0107***	-0.0044	-0.0016
	(0.005)	(0.004)	(0.003)	(0.002)
Constant	-0.1972**	-0.1161**	-0.2223***	-0.1408***
	(0.083)	(0.049)	(0.063)	(0.041)
Observations	3,580	3,540	3,320	3,325
Number of firms	105	104	123	123
R2	0.0654	0.0703	0.0638	0.0548
Adj R2	0.0620	0.0669	0.0601	0.0511

Table 8: The table reports the results of the fixed effect panel regression relative to the all sample defined by equation 6. In this table we test two alternative specifications. The columns under "Balanced" reports the coefficients for those listed firms having non-missing observations at least for the 80% of the period of time considered. The "strong balanced" case reports the coefficients for the same firms in both periods. Standard errors clustered by firm are in parentheses. *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021
	Balanced				Strong Balanced			
$VaR_{99,QPYYYY-QPYYYY}$	0.0237		0.0471***		0.0604**		0.0507***	
	(0.016)		(0.006)		(0.027)		(0.007)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0404***		0.0467***		0.0661***		0.0512***
		(0.013)		(0.005)		(0.019)		(0.006)
Size	-0.0006**	-0.0001	0.0003	0.0001	-0.0002	0.0001	0.0002	-0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Controls and Constant	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,117	3,077	2,240	2,245	1,651	1,651	1,608	1,639
Number of firms	75	74	56	56	39	39	39	40
R2	0.553	0.589	0.380	0.352	0.594	0.635	0.417	0.373
Adj R2	0.551	0.587	0.377	0.348	0.590	0.632	0.413	0.368

specification is to consider only listed firms that have been run their business in both periods, in this case, the *strong balanced* one, we run the analysis for the same sample of firms in both sub-periods. The results are collected in Table 8. The first four columns show that the VaR at 95% and 99% has a positive and significant effect on $\Delta CoVaR$, and that the effect is stronger in the second period. By contrast, in the *strong balanced* case, the VaR has a positive and significant impact on $\Delta CoVaR$ but the impacts seems reducing from the first to the second period, even though the magnitude is higher than baseline results in Table 5.

7.4 Removing the COVID outbreak

In order to corroborate our results, we run the regressions by excluding the period after COVID-19 outbreak (from Q12020 to Q42021). With this further robustness, we control for the possibility that our results be driven by the turbulence induced by the pandemic. The results are collected in table 9. Empirical findings show that, when we exclude the pandemic period, VaR at has a positive and significant effect on $\Delta CoVaR$ and the effect is stronger if compared with the results in table 5 (and in stronger than the evidence of periods 2000-2010 and 2011-2021). For he VaR at 99% (95%) (column I and IV in table 9), we note it has an impact equals to 0.061 (0.056) on $\Delta CoVaR$. Column II and V reports the coefficients when we interact VaR with *Size*. The variables VaR and *Size* have a negative and significant impact to $\Delta CoVaR$. Differently, their interaction is positive and significant as in table 11. Figure 6 shows the relation between the composite effect across different *Size* levels. Graphs (a) and (b) reports the coefficients evo-

Table 9: The table reports the results of the fixed effect panel regression in equation (6)by excluding the first two quarters of 2020 (Covid Outbreak). Clustered standard errors in parentheses *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

	Q12011-Q42019					
	Δ_CoVaR99			Δ_CoVaR95		
VARIABLES	I	II	III	IV	V	VI
$VaR_{99,QPYYYY-QPYYYY}$	0.0614***	-0.0824**	0.6517***			
	(0.007)	(0.035)	(0.195)			
$VaR_{99,QPYYYY-QPYYYY}$ *Size		0.0074***	-0.0686***			
		(0.002)	(0.021)			
$VaR_{99,QPYYYY-QPYYYY}$ $*Size^2$			0.0019***			
			(0.001)			
$VaR_{95,QPYYYY-QPYYYY}$				0.0565***	-0.0785**	0.1605
				(0.005)	(0.031)	(0.160)
$VaR_{95,QPYYYY-QPYYYY}$ *Size					0.0067***	-0.0177
					(0.002)	(0.017)
$VaR_{95,QPYYYY-QPYYYY}$ $*Size^2$						0.0006
						(0.000)
Size	-0.0001	-0.0019***	0.0151***	0.0001	-0.0008***	0.0017
	(0.000)	(0.001)	(0.005)	(0.000)	(0.000)	(0.002)
$Size^2$			-0.0004***			-0.0001
			(0.000)			(0.000)
Controls and Constant	YES	YES	YES	YES	YES	YES
Observations	2,782	2,782	2,782	2,782	2,782	2,782
Number of firms	118	118	118	118	118	118
R2	0.340	0.361	0.372	0.347	0.362	0.363
Adj R2	0.337	0.357	0.369	0.344	0.358	0.359

lution with when VaR is at 99% and 95%. The joint effect is significant for firms' size grater the M$ 2.6 and M$ 1.62 respectively. The impact is comparable with graph (b) and (d) in figure 4.

Panel C reports the regression results when we interact VaR with $Size$ and $Size^2$. In figure 7 the left plots have already been reported in section 6. The effect of size is significant only for firms greater than M$884 (a) and M$14.7 (c) (quantile 99% and 95%). The right part of the panel reports the joint coefficient in 2011-2019. The joint coefficient is always significant considering the risk measures with quantile at 99%. Nevertheless, when we look at the quantile at 95% the effect is significant for those firms having $Size$ values greater than M$1.2 (see panel(d)). Surprisingly, if we compare the 2011-2021 period in figure 4 and 5 with 2011-2019 in figure 6 and figure 7, the latter graphs have a sharper slope. The sensitivity to the size is higher when exclude the last two years.[12]

[12] As robustness check, we also compute the regression in equation 6, 7 and 8 by taking in account the period 2020-2021. The results are not significant.

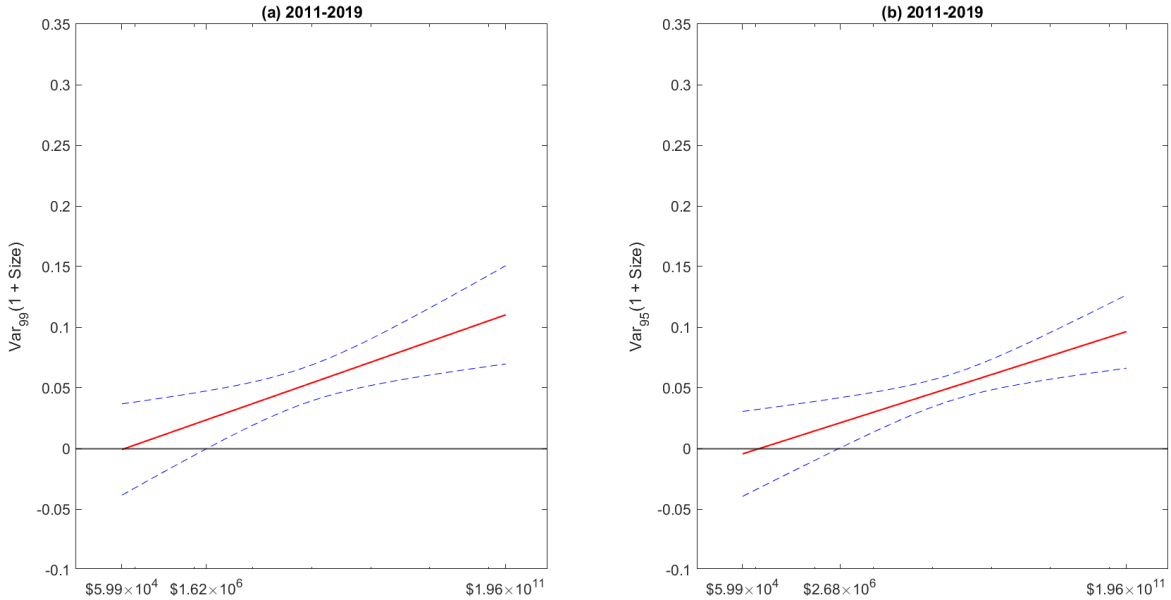

Figure 6: The figure shows the pattern of the joint coefficient $VaR + VaR \times Size$ (red line) with respect to $Size$. The blue dashed lines represent the confidence interval at 99%.

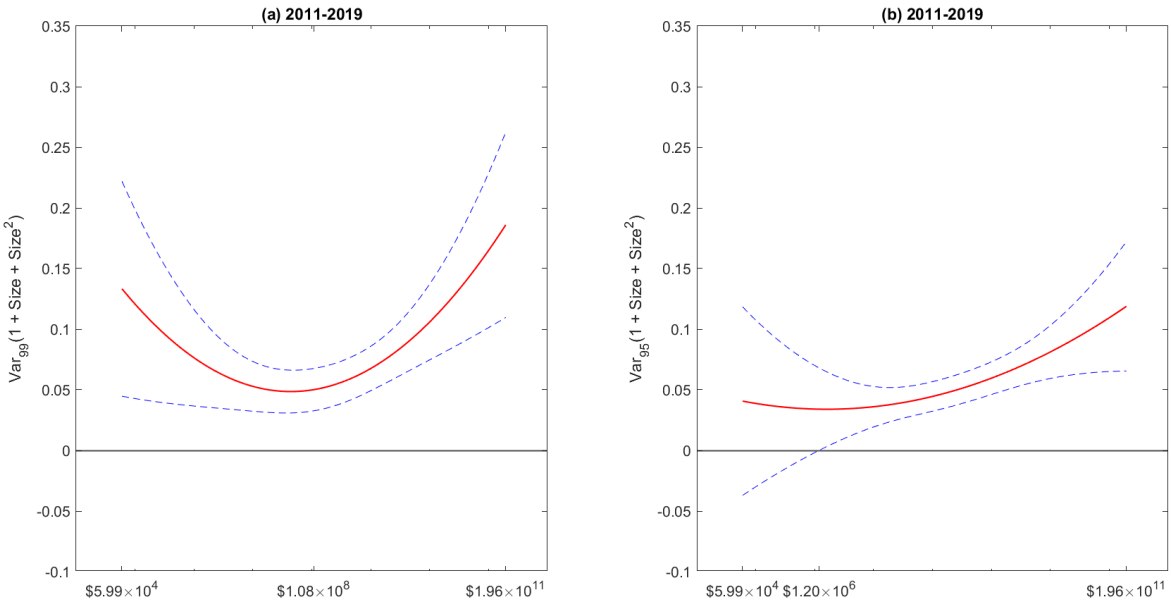

Figure 7: The figure shows the pattern of the joint coefficient $VaR + VaR \times Size + VaR \times Size^2$ (red line) with respect to $Size$. The blue dashed lines represent the confidence interval at 99%.

8 Conclusion

This paper contributes to the literature on systemic risk by providing an empirical analysis on the US Oil and Natural Gas sector. We find that the diffusion of the shale production, starting from

2011 until now, released its burden cost on the US Oil and Natural Gas companies by raising more debt and increasing overall their level of risk. In this respect, our empirical findings show that the company's losses, as summarized by the VaR at 95% and 99% are $\Delta CoVaR$ predictors with an effect stronger in the second period where the shale oil technology is more relevant. Besides, in this period the traditional drivers are less relevant if compared to 2000-2010. Additional results highlight that the size effect interaction with losses is milder in the second period showing that the impact of the Oil and Natural Gas companies on $\Delta CoVaR$ is more homogeneous and slightly related to the firm's size. Robustness checks found that effect is stronger and the difference between the two periods is marked when we change the measure to compute the $\Delta CoVaR$. The Extraction of Natural Gas and support activities sector are those subgroups for which the impact on $\Delta CoVaR$ is higher and the break between the two period appears more net with respect to Extraction of Crude Oil. The results are still valid (i) when we take in account firms having available observations more than 80% of the time horizon; (ii) when we exclude observations after the COVID pandemic outbreak.

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9 Appendix

Table 10: Variable definitions and sources

N	Code	Description	Source
1	Tbill3M	Three-month Treasury bill rate Changes	Refinitiv
2	Term_spread_10Y3M	Difference between the composite 10 year bond yield and the three-month bill rate	Refinitiv Refinitiv
3	Ted_spread	Difference between the three-month LIBOR rate and the three-month secondary market Treasury bill rate.	Refinitiv
4	Credit_spread	Difference between ICE bank of america BBB US Corporate Index and treasury 10 year bond yield	Refinitiv
5	Ret_{MKT}	Standard and Poor 500 Market Index return	Refinitiv
6	Ret_{WTI}	Crude Oil-West Texas Intermediate return	Refinitiv
7	$Ret_{HenryHub}$	United States, Natural Gas, Prices, Henry Hub Spot, USD	Refinitiv
8	$Price_{WTI} - Price_{BRE}$	Difference between the Crude Oil-West Texas Intermediate price and European Brent oil	Refinitiv
9	Δ VIX	Russel volatility index change	Refinitiv
10	Inflation Rate	Changes of all Urban Consumers, United States City Average	Refinitiv
11	Oil	Petroleum and Natural Gas industry portfolio return	French library
12	Debt	Natural logarithim of all interest bearing and capitalized lease obligations.	Refinitiv
13	Size	Natural logarithim of market capitalization	Refinitiv
14	ROA	Ratio between Operating Income and Total Asset	Refinitiv
15	ROE	Ratio between Operating Income and Total Asset	Refinitiv
16	$\Delta NRIGS_{5\%}$	Weekly census change in percentage of the number of Oil drilling rigs actively exploring for or developing oil or natural gas in the U.S.	Baker Hughes North American Rotary

Table 11: The table reports all the coefficients of the fixed effect panel regression defined by equation (6). Standard errors clustered by firm in parentheses *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021	Δ_CoVaR99 Q12011-Q42020	Δ_CoVaR95 Q12011-Q42020	Δ_CoVaR99 Q12011-Q42019	Δ_CoVaR95 Q12011-Q42019
$VaR_{99,QPYYYY-QPYYYY}$	0.0253*		0.0494***		0.0553***		0.0614***	
	(0.014)		(0.006)		(0.007)		(0.007)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0405***		0.0422***		0.0431***		0.0565***
		(0.011)		(0.004)		(0.005)		(0.005)
Ted_spread	1.0060***	0.5004***	1.0903***	0.5630***	0.8532***	0.5688***	0.4012**	0.1798**
	(0.142)	(0.073)	(0.143)	(0.076)	(0.137)	(0.085)	(0.182)	(0.085)
Credit_spread	0.4473***	0.1829***	0.0894*	0.0604**	0.1193**	0.0887***	0.1270**	0.1191***
	(0.064)	(0.027)	(0.052)	(0.024)	(0.047)	(0.026)	(0.052)	(0.024)
Tbill3M	-0.0500*	-0.0036	-0.4471***	-0.4483***	-0.6252***	-0.5778***	-0.2918***	-0.1284***
	(0.028)	(0.014)	(0.077)	(0.051)	(0.076)	(0.057)	(0.091)	(0.045)
Oil sector return	0.2197***	0.1322***	-0.0444***	-0.0280***	-0.0434***	-0.0262***	-0.0415***	-0.0267***
	(0.015)	(0.008)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)
Inflation rate	0.0021***	0.0014***	0.0015***	0.0010***	0.0020***	0.0014***	0.0019***	0.0012***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size	-0.0004	-0.0000	0.0004*	0.0001	0.0004**	0.0003**	-0.0001	0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Debt	0.0002*	0.0002*	0.0000	-0.0000	-0.0000	-0.0001**	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ROA	0.2156*	0.0184	0.0412	0.1042**	0.0788	0.1092**	0.0625	0.0005
	(0.126)	(0.108)	(0.064)	(0.040)	(0.060)	(0.043)	(0.103)	(0.047)
ROE	-0.0002*	0.0004***	-0.0025**	0.0002***	-0.0011***	0.0003*	0.0000	-0.0001
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RET_{WTI}	-0.0011	0.0001	-0.0061***	-0.0031***	-0.0041***	-0.0031***	-0.0043***	-0.0024***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
$RET_{HenryHub}$	-0.0035***	-0.0023***	-0.0059***	-0.0038***	-0.0073***	-0.0052***	-0.0061***	-0.0038***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
$\Delta NRIGS_{\%}$	0.0146***	0.0086***	-0.0005	-0.0003	0.0008	-0.0002	-0.0012*	-0.0008**
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Constant	0.0157**	0.0026	0.0020	0.0039	0.0033	0.0006	0.0136**	0.0044*
	(0.007)	(0.004)	(0.005)	(0.002)	(0.005)	(0.003)	(0.006)	(0.002)
Observations	3,580	3,540	3,320	3,325	3,114	3,122	2,782	2,782
Number of firms	105	104	123	123	121	122	118	118
R2	0.565	0.605	0.362	0.378	0.347	0.363	0.340	0.347
Adj R2	0.563	0.603	0.360	0.375	0.345	0.361	0.337	0.344

Table 12: The table reports all the coefficients of the fixed effect panel regression defined by equation 7. The table reports the coefficients by introducing the interaction between *VaR* and *Size*. Standard errors clustered by firm are in parentheses. *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021	Δ_CoVaR99 Q12011-Q42020	Δ_CoVaR95 Q12011-Q42020	Δ_CoVaR99 Q12011-Q42019	Δ_CoVaR95 Q12011-Q42019
$VaR_{99,QPYYYY-QPYYYY}$	-0.1577***		-0.0558*		-0.0876***		-0.0824**	
	(0.055)		(0.029)		(0.032)		(0.035)	
$VaR_{99,QPYYYY-QPYYYY}$ *Size	0.0100***		0.0053***		0.0072***		0.0074***	
	(0.004)		(0.002)		(0.002)		(0.002)	
$VaR_{95,QPYYYY-QPYYYY}$		-0.2879***		-0.1073***		-0.1257***		-0.0785**
		(0.028)		(0.026)		(0.027)		(0.031)
$VaR_{95,QPYYYY-QPYYYY}$ *Size		0.0184***		0.0075***		0.0084***		0.0067***
		(0.002)		(0.001)		(0.001)		(0.002)
Size	-0.0036***	-0.0029***	-0.0010**	-0.0010***	-0.0014***	-0.0009***	-0.0019***	-0.0008***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Ted_spread	1.0080***	0.3847***	1.1527***	0.6632***	0.9085***	0.6788***	0.3951**	0.2087***
	(0.159)	(0.048)	(0.140)	(0.072)	(0.134)	(0.084)	(0.157)	(0.077)
Credit_spread	0.3746***	0.1028***	0.0464	0.0185	0.0699	0.0466*	0.0880*	0.1015***
	(0.082)	(0.020)	(0.055)	(0.020)	(0.046)	(0.024)	(0.049)	(0.022)
Tbill3M	0.0285	0.0636***	-0.4603***	-0.4633***	-0.6306***	-0.5976***	-0.2960***	-0.1349***
	(0.031)	(0.012)	(0.076)	(0.051)	(0.077)	(0.057)	(0.089)	(0.044)
Oil sector return	0.2066***	0.1219***	-0.0448***	-0.0290***	-0.0438***	-0.0269***	-0.0422***	-0.0269***
	(0.014)	(0.008)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)
Inflation rate	0.0022***	0.0015***	0.0015***	0.0010***	0.0020***	0.0014***	0.0019***	0.0012***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Debt	0.0002	0.0001	0.0000	-0.0000	-0.0000	-0.0001**	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ROA	0.1947**	-0.0124	0.0449	0.0883**	0.0405	0.0696*	0.0309	-0.0125
	(0.096)	(0.061)	(0.057)	(0.039)	(0.061)	(0.040)	(0.102)	(0.045)
ROE	-0.0002**	0.0003***	-0.0028**	0.0004***	-0.0010***	0.0004***	0.0002	-0.0000
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RET_{WTI}	-0.0013*	0.0007	-0.0060***	-0.0032***	-0.0039***	-0.0032***	-0.0036***	-0.0022***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
$RET_{HenryHub}$	-0.0037***	-0.0024***	-0.0059***	-0.0039***	-0.0073***	-0.0053***	-0.0059***	-0.0038***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
$\Delta NRIGS_{\%}$	0.0144***	0.0087***	-0.0007	-0.0005*	0.0008	-0.0004	-0.0013*	-0.0009**
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Constant	0.0790***	0.0582***	0.0302***	0.0270***	0.0403***	0.0262***	0.0498***	0.0227***
	(0.013)	(0.005)	(0.009)	(0.004)	(0.008)	(0.004)	(0.010)	(0.005)
Observations	3,580	3,540	3,320	3,325	3,114	3,122	2,782	2,782
Number of firms	105	104	123	123	121	122	118	118
R2	0.590	0.675	0.371	0.397	0.362	0.383	0.361	0.362
Adj R2	0.588	0.674	0.368	0.394	0.359	0.381	0.357	0.358

Table 13: The table reports all the coefficients of the fixed effect panel regression defined by equation 8. The table reports the coefficients by introducing the interaction between VaR and $Size$ and VaR and $Size^2$. Standard errors clustered by firm are in parentheses. *** p<0.01, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	Δ_CoVaR99 Q12000-Q42010	Δ_CoVaR95 Q12000-Q42010	Δ_CoVaR99 Q12011-Q42021	Δ_CoVaR95 Q12011-Q42021	Δ_CoVaR99 Q12011-Q42020	Δ_CoVaR95 Q12011-Q42020	Δ_CoVaR99 Q12011-Q42019	Δ_CoVaR95 Q12011-Q42019
$VaR_{99,QPYYYY-QPYYYY}$	0.3465**		0.1532		0.3159**		0.6517***	
	(0.135)		(0.161)		(0.140)		(0.195)	
$VaR_{99,QPYYYY-QPYYYY}$ *Size	-0.0479***		-0.0165		-0.0338**		-0.0686***	
	(0.015)		(0.016)		(0.015)		(0.021)	
$VaR_{99,QPYYYY-QPYYYY}$ $*Size^2$	0.0016***		0.0006		0.0010***		0.0019***	
	(0.000)		(0.000)		(0.000)		(0.001)	
$VaR_{95,QPYYYY-QPYYYY}$		0.0127		0.1077		0.1159		0.1605
		(0.120)		(0.159)		(0.167)		(0.160)
$VaR_{95,QPYYYY-QPYYYY}$ *Size		-0.0156		-0.0144		-0.0159		-0.0177
		(0.013)		(0.016)		(0.017)		(0.017)
$VaR_{95,QPYYYY-QPYYYY}$ $*Size^2$		0.0010***		0.0006		0.0006		0.0006
		(0.000)		(0.000)		(0.000)		(0.000)
Size	-0.0067	-0.0102***	0.0011	0.0009	0.0074*	0.0019	0.0151***	0.0017
	(0.006)	(0.002)	(0.004)	(0.002)	(0.004)	(0.003)	(0.005)	(0.002)
$Size^2$	0.0001	0.0002***	-0.0001	-0.0000	-0.0002**	-0.0001	-0.0004***	-0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ted_spread	0.8640***	0.2987***	1.1537***	0.6672***	0.9047***	0.6817***	0.4076***	0.2097***
	(0.152)	(0.039)	(0.139)	(0.071)	(0.132)	(0.083)	(0.154)	(0.075)
Credit_spread	0.3388***	0.0933***	0.0418	0.0169	0.0602	0.0431*	0.0655	0.0997***
	(0.083)	(0.018)	(0.054)	(0.020)	(0.046)	(0.023)	(0.048)	(0.021)
Tbill3M	0.0511	0.0687***	-0.4690***	-0.4656***	-0.6392***	-0.5986***	-0.3147***	-0.1382***
	(0.032)	(0.012)	(0.076)	(0.051)	(0.078)	(0.057)	(0.086)	(0.043)
Oil sector return	0.2067***	0.1236***	-0.0453***	-0.0294***	-0.0443***	-0.0271***	-0.0430***	-0.0270***
	(0.015)	(0.008)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)
Inflation rate	0.0021***	0.0015***	0.0015***	0.0010***	0.0020***	0.0014***	0.0019***	0.0012***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Debt	0.0002	0.0001	0.0000	-0.0000	-0.0000	-0.0001**	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ROA	0.2446**	0.0271	0.0581	0.0904**	0.0408	0.0776*	0.0124	-0.0094
	(0.095)	(0.058)	(0.062)	(0.039)	(0.060)	(0.040)	(0.097)	(0.045)
ROE	-0.0001	0.0004***	-0.0028**	0.0004***	-0.0011***	0.0003**	0.0000	-0.0000
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RET_{WTI}	-0.0016**	0.0006	-0.0060***	-0.0031***	-0.0038***	-0.0031***	-0.0034***	-0.0021***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
$RET_{HenryHub}$	-0.0038***	-0.0024***	-0.0059***	-0.0038***	-0.0073***	-0.0053***	-0.0058***	-0.0038***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
$\Delta NRIGS_{\%}$	0.0142***	0.0086***	-0.0007	-0.0005*	0.0008	-0.0004	-0.0013*	-0.0009**
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Constant	0.1132*	0.1279***	0.0100	0.0083	-0.0471	-0.0017	-0.1176**	-0.0017
	(0.058)	(0.023)	(0.046)	(0.024)	(0.041)	(0.026)	(0.050)	(0.024)
Observations	3,580	3,540	3,320	3,325	3,114	3,122	2,782	2,782
Number of firms	105	104	123	123	121	122	118	118
R2	0.611	0.695	0.372	0.398	0.364	0.384	0.372	0.363
Adj R2	0.609	0.694	0.369	0.395	0.361	0.381	0.369	0.359