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The predictive power of the oil variance risk premium

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ABSTRACT

This paper examines the ability of the oil market variance risk premium (VRP) to predict both financial and key macroeconomic series. Interest in understanding the movement of such variables increasingly involves considering measures of investor risk, for which the VRP, that incorporates both implied and realised variance, has recently come to the fore. It is well established that oil price movement impacts both the stock market and wider economy and thus, we examine whether this is also true of the oil VRP. Using monthly US data over the period from 2009 to 2021, we demonstrate the nature of oil VRP predictive power for oil and stock returns, as well as output growth, unemployment, and inflation. Of notable interest, while predictability from the oil VRP series dominates at the one-month horizon and (largely) wanes at over longer time periods, the reverse is found for the stock VRP. These results are robust to the inclusion of additional, established, predictor variables. This indicates that the impact of oil market risk has a more immediate effect on both the stock market and economy, with stock market risk reflecting longer term considerations. A simple out-of-sample exercise supports the view that the inclusion of oil VRP improves forecasts over alternative models that exclude this series.

1. Introduction

Understanding movements in the market risk premium is important for asset price behaviour, return dynamics, and for the wider economy. Research seeks to identify improved indicators of investor risk appetite that will impact upon their asset allocation decisions. Such decisions, and changes in risk appetite, are based on investor expectations of future macroeconomic performance. Therefore, movements in such a risk indicator will act as a predictor both for key market and economic variables and will be of use to (other) investors and policymakers. That is, both in terms of portfolio adjustment and pre-emptive policy action.

One such measure is the stock market variance risk premium (VRP), which captures the difference between market implied (IV) and realised (RV) variance. The former is typically proxied by VIX and thus, the markets view of expected variance (based on S&P500 option prices) and is well-known as a 'fear index' (Whaley, 2000). While RV can be calculated in different ways and, most prominently, is based on the aggregation of higher frequency squared returns to the lower frequency of interest. This estimate of conditional market variance is typically found to provide a more accurate representation of variance than alternative approaches (Andersen and Bollerslev, 1998; Andersen et al., 2001; Barndorff-Nielsen and Shephard, 2002). These 'model-free' approaches thus capture ex-ante (VIX) and ex-post (RV) measures of variance and the difference between them represents the VRP, which proxies for investor risk aversion (see, for example, Carr and Wu, 2009).[1] Previous work identifies the VRP as a predictor for both stock returns and macroeconomic variables (see, for example, Bollerslev et al., 2009; Bekaert and Hoerova, 2014; Chow et al., 2020).

Movements in the oil market represent one of the dominant risk factors for the global economy. In a series of papers, Hamilton (1983, 1996, 2003) argues that an oil price rise precedes a recessionary period in the US.[2] Thus, an understanding of movements in the oil market is an important indicator for subsequent macroeconomic performance. In related work, Jones and Kaul (1996) note that movements in the oil price impact US stock returns. Further work, including Sadorsky (1999), Lescaroux and Mignon (2008), Park and Ratti (2008), Kilian and Park

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[1] Being 'model-free' reduces the element of estimation error in the construction of the variable.

[2] The rationale for this effect is several and includes an increase in the costs of production, especially through energy costs, which effects firms. Households are also impacted by higher bills and fuel costs. Both of these lead to a reduction in spending by firms and households. The rise is costs also leads to higher inflation and therefore corrective action by policymakers that can have a further dampening effect on the economy.

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(2009) and Diaz et al. (2016) all argue that movements in oil price and volatility impact both economic activity and stock market performance. Recent work also highlights the key role oil plays in determining interrelations across international stock markets (see, for example, Zhang, 2017; McMillan et al., 2021).

Thus, a natural extension is to consider whether an equivalent oil market VRP contains predictive power not only for oil returns themselves, but for a wider selection of market and economic variables, as is currently reported for stock VRP. Moreover, we can examine whether information contained within the oil VRP differs from that of the stock VRP as well as other market predictors. Therefore, using a series of regressions, this paper considers the ability of the oil VRP to predict both oil and stock returns as well as several key macroeconomic series over a range of horizons while incorporating standard predictors as control variables. An ability to predict market movement is of interest to investors seeking to manage their portfolio, while an ability to predict macroeconomic variables is of interest to policymakers who can use the information to adjust policy instruments. Overarching, the results are of interest to those engaged in understanding and modelling the relation between markets and the macroeconomy.

This paper obtains monthly US data, over the period 2009 to 2021 to examine the predictability not only oil and stock returns but also important macroeconomic variables, including growth, unemployment, and inflation using constructed oil and stock VRP series while including standard control variables (dividend-price ratio and interest rate series). The results reveal two key insights. First, oil VRP exhibits significant predictive power for both financial and macroeconomic series. Notably, a negative predictive relation is reported for oil returns, output growth and inflation, with a positive predictive relation for stock returns, unemployment, and inflation expectations. These results are consistent with higher oil market risk having a negative impact on subsequent expected economic performance. Second, examining the results across several time horizons reveals that while predictability over a longer period wanes for oil VRP, it strengthens for stock VRP. This indicates that oil market risk has an immediate impact on both financial markets and the wider economy, while that emanating from the stock market carries longer term information.

It is believed that this paper contributes to the literature and our understanding of markets by examining the nature of risk, primarily, within the oil market but also the stock market. Notably, considering how this impacts both financial markets and the real economy over differing horizons. This is important for investors in knowing how changes in risk affect portfolios and for policymakers in being able to adjust policy instruments based on the nature of risk signals emanating from these markets.

2. Background

In this section, we first consider key issues in the development and construction of the variance risk premium and, second, briefly discuss recent literature that examines the predictive power of such a risk measure.

2.1. Variance risk premium

In seeking to understand the movement of asset prices as well as the links between financial and real markets, interest is increasingly drawn towards measures that capture investor perceptions of risk. Moreover, together with a desire for a 'model-free' approach, this has led to the consideration of realised and implied variance measures, with both becoming well-known. For the latter, the VIX, implied volatility index, is typically used and captures the market 'risk-neutral' expectation of volatility over the near future and is based on option contracts for the S&P500. The realised variance measure captures current market volatility and is based on intra-day data that offers a more accurate representation of the (unobserved) stock return variance (e.g., Andersen and Bollerslev, 1998; Andersen et al., 2001).

Based on these definitions, several researchers (in addition to those cited in the Introduction, see also, Bollerslev and Todorov, 2011; Bollerslev et al., 2015; Andreou and Ghysels, 2021) note that the difference between these measures, the risk-neutral market implied volatility and an estimate of conditional variance of the market, represents the variance risk premium (VRP).[3] That is:

$$VRP_t = IV_t - RV_t \tag{1}$$

where IV_t represents the implied variance measure and RV_t the realised variance measure. Although, as discussed in Zhou (2018), any appropriate measure for implied and realised variance could be used in equation (1), as noted, common practice is to use the VIX index and the realised variance measures based on high frequency data.

A more notable issue is the specification of equation (1), which differs across previous work. This arises as the IV element is an ex-ante measure of expected future volatility, while RV is an ex-post measure. Strictly speaking, in equation (1), both IV and RV are expected values over the period [t, t+1]. The VIX, as an ex-ante measure, satisfies this need for the IV term. Moreover, several papers use the squared VIX as the risk-neutral conditional variance measure. However, as RV is an ex-post measure, this requires an estimate of $E_t(RV_{t+1})$ i.e., the expectation of subsequent realised variance. The literature considers several alternatives including the use of RV_t, the ex-post use of RV_{t+1}, or an explicit forecast model for $E_t(RV_{t+1})$ (see, for example, Bollerslev et al., 2009; Zhou, 2018; Bekaert and Hoerova, 2014). Of note, the use of RV_t implies random walk behaviour within RV, which is generally not observed. Further, while Bekaert and Hoerova (2014) argue that different approaches affect the estimate of VRP and its predictive ability, Andreou and Ghysels (2021), albeit it a slightly different context, note some robustness across measures.

In deriving the VRP, Bollerslev et al. (2009) use the difference between IV and RV, as indicated in equation (1), while they also consider the square root of each series as well as alternative approaches to deriving the VRP with qualitatively similar results. Our main approach here, however, is to follow Bekaert and Hoerova (2014), also used by, for example, Chow et al. (2020) and Qadan and Shuval (2021) and construct the VRP as:

$$VRP_t = IV_t^2 - E_t(RV_{t+1}) \tag{2}$$

where IV_t^2 is captured by the VIX and $E_t(RV_{t+1})$ is obtained using three broad alternative approaches. First, we use RV_t as a proxy, second, we estimate an AR(1) model for (RV_{t+1}) and third, we estimate the HAR model of Corsi (2009) for $E_t(RV_{t+1})$, which is the measure used in the reported results below.

2.2. Brief Literature Review

As noted in the Introduction, this paper considers two current lines of research, relating to the oil market and the VRP, combining them to examine their ability to predict both financial and macroeconomic variables. The contribution in this paper is to provide a robust set of results.

In one line of research, work notes the influence of the oil market on both stock markets and economic conditions. Most notably, this began with the work of Hamilton (1983, 1996, 2003) and expanded in several directions, for example, Kilian (2005), Cologni and Manera (2008) and Smyth and Narayan (2018). Higher oil prices and an increase in risk in the oil market can have a dampening effect on the macroeconomy. This

[3] More formally, Bollerlsev et al. (2009) and Carr and Wu (2009) among others, show that VIX can be decomposed into a variance risk premium and expected market volatility, from which equation (1) backs out the variable of interest.

arises as higher prices impact a firm's future earnings (e.g., Mohanty and Nandha, 2011), leading to lower levels of output and higher prices. This, in turn, can cause policymakers to increase policy rates as oil prices impact production costs and lead to inflationary pressure (e.g., Basher and Sadorsky, 2006). Both of these effects can equally impact stock prices, affecting both expected future cash flows and discount rate attached to them (e.g., Sadorsky, 1999). Recent work considers the impact of the oil market across a range of financial market dynamics (e.g., Abhyankar et al., 2013; Ready, 2018; Demirer et al., 2020; McMillan et al., 2021).

A separate line of research considers the ability of VRP within stock markets to predict not only stock returns but also macroeconomic variables. Notably, this includes Bollerslev et al. (2009), Bekaert and Hoerova (2014), Bollerslev et al. (2014) and Li and Zinna (2018). The results here, however, are mixed. For example, Bekaert and Hoerova (2014) report that there is greater evidence of predictability for output growth from realised volatility compared to VRP. Similarly, Bollerslev et al. (2009) note some variability in the strength of predictive power for stock returns over different horizons. More recently, McMillan (2023) examines the predictive ability of VRP and the default yield, as risk measures arising from the stock and bond markets respectively, to predict four macroeconomic series, with broadly supportive results. This also ties to a separate line of research that considers the ability of financial markets to predict the real economy, see, for example, Stock and Watson (2003), McMillan and Wohar (2012) and Kuosmanen and Vataja (2019).

In this paper, we connect these two stands of research and consider whether a VRP for the oil market can predict not only oil returns, but also stock and macroeconomic variables. To date, only Kang and Pan (2015) consider the predictive ability of the oil market VRP and only to predict oil returns.

3. Data and method

We utilise monthly data over the period from 2009M9–2021M2, with the start of the sample limited by data availability, although daily and intra-day data is used in the construction of the oil and stock VRP series.[4] We identify six key variables that we seek to predict using the oil VRP. These variables are oil and stock returns, which are of importance to investors and portfolio managers and four macroeconomic series that are monitored by policymakers when determining appropriate policy action. The macroeconomic series are industrial production growth, the change in unemployment and two measure of inflation (inflation itself, as the change in CPI, and inflation expectations based on the difference between 10-year Treasury bonds and the equivalent inflation indexed bonds). As noted in the Introduction and Literature Review sections, changes in the oil market have the potential to affect each of these macroeconomic variables as they have a direct impact on production costs and therefore, output, employment, and prices, as well as potentially initiating a policy response.

The macroeconomic data is obtained from the St Louis FRED database, with the stock index series used to generate returns from the website of Robert Shiller.[5] The key predictor variable is the oil VRP, with the oil VIX also obtained from FRED and the oil RV series from the website of Dacheng Xiu.[6] For the stock VRP, the VIX is likewise obtained from FRED and the RV from the (now discontinued) Oxford Man realised volatility database. For the control variables, the (log) dividend yield is obtained from Shiller, while the term structure (10-year minus 3-month Treasuries) and default yield (yield on BAA rated corporate bonds minus 10-Year Treasuries) are obtained from FRED.[7] In recent work, as discussed above, McMillan (2023) presents evidence that the stock VRP and default yield has predictive power for several of the series considered here. While there is evidence for the dividend yield and term structure exhibiting similar predictive power due to movements in risk. See, for example, Cochrane (2011) for a discussion of the former and Evgenidis et al. (2020) for a review of the latter.

Summary statistics and graphs are presented in Table 1 and Fig. 1 respectively. Inevitably, the graphical representation of the data is dominated by the Covid19 crash, for which we see a large negative value for oil and stock returns, as well as for output growth, inflation, and inflation expectations. The term structure turns negative, which commonly signals a recession, while there is an increase in the default yield, which indicates an increase in macroeconomic risk. Consistent with this, both the oil and stock variance risk premium measures show a notable increase as does the change in unemployment. The summary statistics in Table 1 present no unusual patterns for financial and macroeconomic data and for the period analysed. As evident in combination with Fig. 1, the large minimum and maximum values are associated with the Covid19 period.

Using, primarily, the oil VRP as well as the stock VRP and control variables, we seek to predict the six identified variables using the following standard predictive regression:

$$y_{t+k} = \alpha + \Sigma_i \beta_i x_{i,t-1} + \varepsilon_{t+k} \quad (3)$$

where y_t represents the oil return, stock return, industrial production growth, change in unemployment, inflation and change in inflation expectations measured over k horizons respectively, x_t are the oil VRP, stock VRP, log dividend yield, term structure and default yield predictor variables and ε_t is a white noise error term.[8] We consider several alternatives of the predictive regressions to ensure robustness. For the predictive horizon, we consider $k = 1$, 3, 12 and thus, one-month, one-quarter, and one-year. In estimating the above regression, we include, first, just the oil VRP, second, both the oil and stock VRP series and third, all predictor variables. We also include the individual VRP components (VIX and RV) in separate regressions.[9]

4. Empirical results

Table 2 presents the estimation results of equation (3) where the oil and stock returns series are predicted for $k = 1$ (i.e., one-month horizon) using the oil and stock VRP series and their constituents (i.e., VIX and RV) as predictor variables. From these results we can see that the oil VRP exhibits predictive power for oil returns when included individually (Model 1) and jointly with the stock VRP (Model 3). The relation is negative, indicating that an increase in the oil VRP leads to lower subsequent oil returns. The stock VRP also has a negative coefficient, although it is statistically insignificant. We also include the oil VIX and RV as separate variables, and again both without (Model 2) and with (Model 4) the corresponding stock variables. Here we can see that

[4] In regard of data availability, the start of the sample period is governed by the availability of oil RV data (see the note below). The end of the sample period is limited by the discontinuing of the stock RV database (also see the comment below).

[5] http://www.econ.yale.edu/~shiller/data.htm.

[6] https://dachxiu.chicagobooth.edu/#risklab.

[7] The choice of control variables is motivated by those considered in work both directly related to this paper, including Bollerslev et al. (2009) who consider predictive power of the stock VRP, as well as the general predictability literature e.g., Campbell and Shiller (1988), Welch and Goyal (2008) and McMillan (2021).

[8] We use the change in unemployment and inflation expectations to eliminate the high degree of persistence in each series. Although unit root tests indicate stationarity, AR(1) coefficients are over 0.90.

[9] We undertake regressions that include the VRP and RV series together and with the VIX separately. Inevitably, given the nature of the relation in equation (1), these series are highly correlated, and the results are intended to illustrate the nature of the predictive relation. The alternative regressions are available upon request.

Table 1
Summary statistics.

Series	Mean	Median	Min	Max	Std Dev	Skewness	Kurtosis
Oil Return	−0.228	1.075	−56.813	54.562	11.553	−0.887	12.778
Stock Ret	0.966	1.517	−21.156	6.145	3.350	−2.659	16.475
IP Growth	0.010	0.158	−14.610	6.012	1.531	−6.095	65.399
Une Ch.	−0.307	−1.005	−19.416	121.302	11.235	9.331	101.952
Inflation	0.143	0.178	−0.699	0.579	0.209	−0.852	5.216
Infl Exp	1.947	1.970	0.870	2.590	0.326	−0.403	3.073
Oil VRP	15.568	10.222	2.323	288.255	26.312	8.574	86.670
Stock VRP	3.818	2.687	0.892	28.246	3.559	3.448	19.934
Log DP	−3.926	−3.930	−4.180	−3.774	0.069	−0.569	4.059
TS	1.723	1.780	−0.490	3.790	0.984	−0.090	2.361
DFY	2.599	2.610	1.560	3.930	0.457	0.120	2.482

Notes: Entries are summary statistics for the oil return, stock return, growth rate of industrial production, the change in unemployment, inflation, inflation expectations (the difference between 10-year Treasury bonds and their inflation adjusted equivalent), oil variance risk premium (VRP; as defined in equation (2) using the oil VIX and realised volatility), stock VRP (as defined in equation (2) using the stock VIX and realised volatility), the log of the dividend yield, the term structure (the difference between 10-year Treasury bonds and 3-month Treasury bills) and the default yield (the difference between BAA rated corporate bonds and the 10-year Treasury bond). All data is for the US on a monthly basis over the period 2009:9–2021:2.

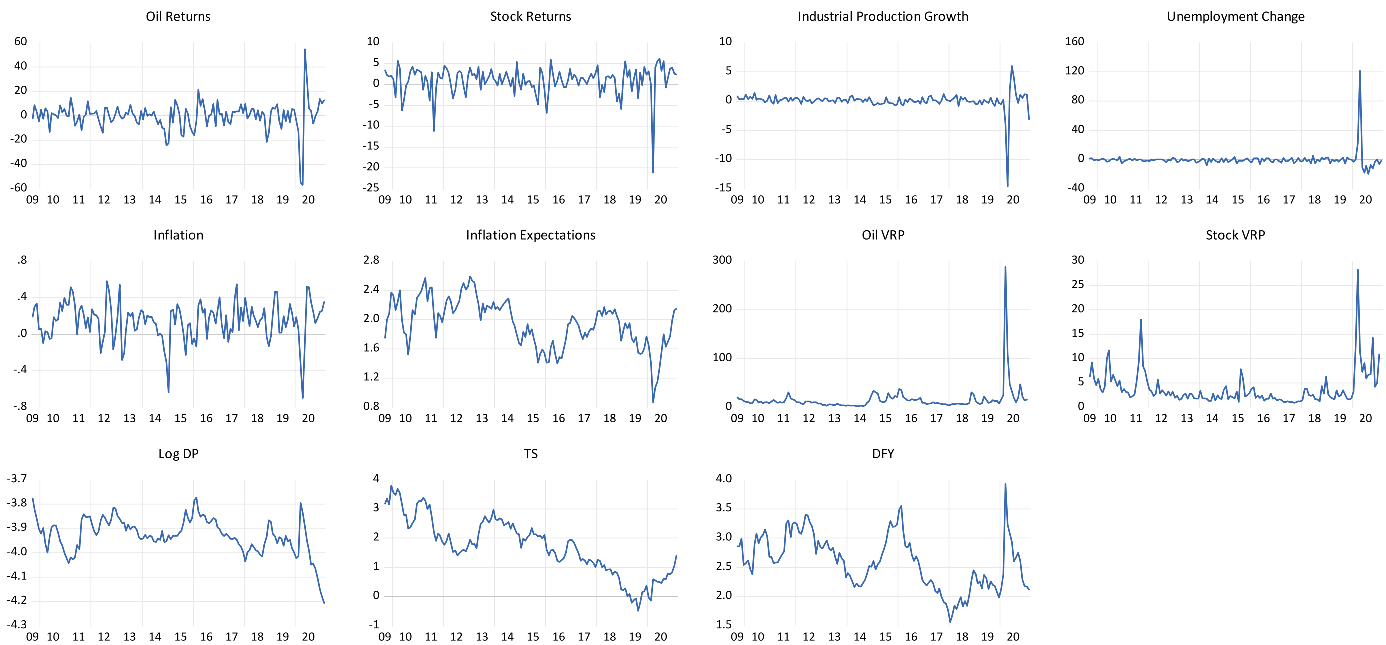

Fig. 1. Time Series Data Plots
Notes: The plots are time-series graphs of each of our data series, oil returns, stock returns, industrial production growth, the change in unemployment, inflation, inflation expectations (10-year Treasuries minus the equivalent inflation indexed bonds, which are used in 'change' form in the analysis to ensure stationarity), oil VRP (variance risk premium), stock VRP, the log of the dividend yield (Log DP), the term structure (TS, 10-year minus 3-month Treasuries) and the default yield (DFY, yield on BAA rated corporate bonds minus 10-year Treasuries).

regardless of whether the stock variables are included, the oil VIX has a negative and significant relation, while the oil RV has a positive and significant relation and whose coefficient has a larger magnitude. Thus, an increase in market implied volatility, which is designed to reflect future conditions, decreases oil returns, while historical volatility leads to higher returns. This is consistent with evidence from stocks (for example, Giot (2005) identifies a negative relation between stock returns and VIX), and indeed, is replicated in the results below.[10]

In predicting stock returns, the oil VRP exhibits a positive and statistically significant result. Again, this is consistent across Models 1 and 2, without and with the stock VRP. Thus, higher risk in the oil market signals higher future expected returns and consistent with a generally held view that higher risk leads to higher future stock returns (i.e., a lower current stock price). Separating the oil VIX and RV has the same effect as for the oil return, however, statistical significance differs. The oil VIX is negative and insignificant while the oil RV is positive and significant. For stock VIX and RV, we see the same coefficient signs, with the former significant only at the 10 % level and latter at the (higher than) 5 % level. The stock VRP itself, however, is not statistically significant.

These results suggest that risk in the oil market has significant predictive power for both oil and stock returns. Of note, the negative relation for the former suggests that an increase in oil VRP leads to a continuing fall in oil prices, while the positive relation for the latter suggest that an increase in oil market risk leads to an immediate fall in stock prices and a higher subsequent (expected) return to accommodate this increase in risk.

Table 3 repeats this analysis for the four macroeconomic variables of industrial production (output) growth, the change in unemployment, inflation, and the change in inflation expectations. As predictor variables, we again consider the oil and stock VRP and their constituent parts. For output growth, oil VRP has a consistently negative predictive

[10] For a wider discussion around stock returns and volatility see Fifield et al. (2020) and Kassa et al. (2021).

Table 2
One-month oil and stock return predictability with VRP and components.

	Oil VRP	Oil VIX	Oil RV	Stock VRP	Stock VIX	Stock RV
Oil Returns						
Model 1	−0.191 (−5.21)					
Model 2		−0.470 (−5.14)	0.735 (4.21)			
Model 3	−0.158 (−2.77)			−0.351 (−0.48)		
Model 4		−0.399 (−3.16)	0.707 (3.68)		−0.163 (−0.45)	−0.109 (−2.18)
Stock Returns						
Model 1	0.013 (2.65)					
Model 2		−0.022 (−1.00)	0.062 (3.35)			
Model 3	0.034 (2.03)			−0.220 (−0.95)		
Model 4		−0.046 (−1.36)	0.095 (3.49)		−0.241 (−1.85)	0.502 (2.82)

Notes: Entries are the coefficients values (and Newey-West t-statistics) from equation (3), which regresses oil returns (in the top panel) and stock returns (in the lower panel) against the variables noted in the first row (VRP is the variance risk premium, VIX is implied volatility index and RV is realised volatility). The Models 1–4, refer to the inclusion of the different predictor variables.

Table 3
One-month macroeconomic predictability with VRP and components.

	Oil VRP	Oil VIX	Oil RV	Stock VRP	Stock VIX	Stock RV
Industrial Production Growth						
Model 1	−0.039 (−6.97)					
Model 2		−0.079 (−4.06)	0.064 (4.78)			
Model 3	−0.040 (−7.10)			0.005 (0.09)		
Model 4		−0.040 (−4.55)	0.044 (5.19)		0.049 (1.58)	−0.029 (−5.73)
Change in Unemployment						
Model 1	0.341 (6.08)					
Model 2		6.948 (2.45)	−2.544 (−2.94)			
Model 3	0.371 (7.60)			−0.308 (−1.02)		
Model 4		1.662 (2.71)	−0.935 (−4.45)		−5.114 (−3.29)	3.408 (5.53)
Inflation						
Model 1	−0.313 (−11.07)					
Model 2		−0.709 (−8.18)	0.617 (7.39)			
Model 3	−0.231 (−3.13)			−0.865 (−1.03)		
Model 4		−0.441 (−2.56)	0.534 (5.98)		−0.259 (−0.54)	−0.109 (−1.20)
Inflation Expectations Change						
Model 1	0.097 (3.80)					
Model 2		0.009 (1.66)	0.182 (2.81)			
Model 3	0.093 (2.81)			0.038 (0.05)		
Model 4		0.016 (1.14)	0.166 (1.97)		−0.013 (−0.32)	−0.019 (−0.22)

Notes: Entries are the coefficients values (and Newey-West t-statistics) from equation (3), which regresses industrial production growth (first panel), the change in unemployment (second panel), inflation (third panel) and the change in inflation expectations (fourth panel) against the variables noted in the first row (VRP is the variance risk premium, VIX is implied volatility index and RV is realised volatility). The Models 1–4, refer to the inclusion of the different predictor variables.

relation, which is reflected in a negative relation for oil VIX, with a positive relation for oil RV. For the stock market variables, only stock RV has a statistically significant relation, which is negative. Oil VRP has a positive and significant effect on the change in unemployment, consistent with the negative effect on output growth. This is reflected through a positive relation with the oil VIX, whereas the relation with oil RV is negative. While the stock VRP is insignificant, the stock VIX exhibits a negative relation and stock RV a positive one, both of which are significant. Inflation follows a similar pattern to output growth, where oil VRP and oil VIX has a negative relation, while oil RV has a positive relation, with all being significant. None of the stock related variables are significant. This reflects the likelihood of an economic downturn following heighted oil market risk. The relation with the change in inflationary expectations is positive for each of the oil related variables and significant for oil VRP and RV. This change in coefficient sign reflects a differing perspective where the inflation expectations variable is based on 10-year Treasury bonds as opposed to the monthly change in CPI for the above noted inflation variable. This suggests that the heightened oil risk is associated with increased inflation over a longer-term period.

Table 4 presents the predictive results for each variable over the horizons $k = 1, 3, 12$ (i.e., one-month, one-quarter, one-year) using both the oil and stock VRP and components (results are also available for the same regressions using the oil related variables only but are qualitatively similar). The one-month results are the same as those reported in Tables 2 and 3 but are included again to help illustrate the changing nature of predictability across the differing horizons. For the oil return, oil VRP has a significant predict effect at the three-month period and this is also reflected in oil RV, however, there is no predictive power at the one-year horizon. For stock returns, the oil VRP only exhibits significance at the one-month horizon, while stock VRP has increasing positive predictive power that strengthens at the longer horizons.[11,12] Notably, this

[11] Greater evidence of average dependence from oil to stocks is reported by Mensi et al. (2017), who also examine different aspects of the relation including market conditions.

[12] There is an established body of work that identifies stock market risk factors having increased predictive power over longer horizons, see, for example, Cochrane (2008, 2011).

Table 4
Multi-horizon predictability with VRP and components.

		1-Month	3-Month	12-Months
	Oil Return			
Model 1	Oil VRP	−0.158 (−2.77)	0.440 (2.39)	1.033 (1.52)
	Stock VRP	−0.351 (−0.48)	0.730 (1.31)	1.230 (1.64)
Model 2	Oil VIX	−0.399 (−3.16)	0.757 (0.29)	0.647 (0.88)
	Oil RV	0.707 (3.68)	0.305 (3.06)	0.330 (1.75)
	Stock VIX	−0.163 (−0.45)	0.080 (0.18)	0.971 (1.16)
	Stock RV	−0.109 (−2.18)	−0.020 (−0.19)	−0.210 (−0.87)
	Stock Returns			
Model 1	Oil VRP	0.034 (2.03)	0.017 (1.03)	−0.171 (−1.63)
	Stock VRP	−0.220 (−0.95)	0.744 (4.52)	1.205 (3.26)
Model 2	Oil VIX	−0.046 (−1.36)	0.011 (0.16)	−0.062 (−0.44)
	Oil RV	0.095 (3.49)	0.032 (1.52)	0.034 (0.03)
	Stock VIX	−0.241 (−1.85)	2.835 (2.67)	4.106 (2.37)
	Stock R	0.502 (2.82)	0.227 (1.78)	0.541 (0.72)
	Industrial Production Growth			
Model 1	Oil VRP	−0.040 (−7.10)	−0.023 (−2.05)	−0.159 (−2.78)
	Stock VRP	0.005 (0.09)	−0.091 (−0.44)	0.354 (2.23)
Model 2	Oil VIX	−0.040 (−4.55)	0.016 (0.40)	−0.106 (−1.53)
	Oil RV	0.044 (5.19)	−0.098 (−2.88)	−0.007 (−1.96)
	Stock VIX	0.049 (1.58)	−0.452 (−1.02)	1.641 (1.79)
	Stock RV	−0.029 (−5.73)	0.123 (1.04)	−0.069 (−0.19)
	Change in Unemployment			
Model 1	Oil VRP	0.371 (7.60)	0.184 (1.99)	0.108 (0.97)
	Stock VRP	−0.308 (−1.02)	0.521 (0.42)	−1.124 (−0.88)
Model 2	Oil VIX	1.662 (2.71)	0.985 (0.50)	7.159 (1.25)
	Oil RV	−0.935 (−4.45)	−1.302 (−1.92)	−4.878 (−3.13)
	Stock VIX	−5.114 (−3.29)	0.247 (−0.04)	−6.066 (−0.86)
	Stock RV	3.408 (5.53)	2.308 (1.96)	0.082 (0.04)
	Inflation			
Model 1	Oil VRP	−0.231 (−3.13)	−0.050 (−0.26)	0.463 (0.23)
	Stock VRP	−0.865 (−1.03)	−0.185 (−0.80)	0.717 (1.08)
Model 2	Oil VIX	−0.441 (−2.56)	0.012 (1.57)	0.010 (0.56)
	Oil RV	0.534 (5.98)	−0.011 (−1.57)	0.004 (0.03)
	Stock VIX	−0.259 (−0.54)	−0.052 (−0.60)	0.276 (1.22)
	Stock RV	−0.109 (−1.20)	−0.026 (−1.06)	−0.014 (−0.16)
	Inflation Expectations Change			
Model 1	Oil VRP	0.093 (2.81)	0.129 (2.53)	1.216 (3.05)
	Stock VRP	0.038 (0.55)	1.741 (2.72)	3.927 (2.35)
Model 2	Oil VIX	0.016 (1.14)	0.920 (3.05)	1.305 (3.15)
	Oil RV	0.166 (1.97)	−0.158 (−1.06)	0.064 (0.32)
	Stock VIX	−0.013 (−0.32)	9.289 (2.25)	19.477 (3.25)
	Stock RV	−0.019 (−0.22)	−2.862 (−2.48)	−2.847 (−1.73)

Notes: Entries are the coefficients values (and Newey-West t-statistics) from equation (3), which regresses oil returns (first panel), stock returns (second panel), industrial production growth (third panel), the change in unemployment (fourth panel), inflation (fifth panel) and the change in inflation expectations (sixth panel) against the variables noted in the second column. The models are estimated over three time horizons as given by the first row.

predictability also appears with the stock VIX.

Turning to the macroeconomic variables, we see that the oil VRP has negative predictive power for output growth across all horizons, with the oil RV significant. The stock VRP is positive and significant at the one-year horizon, with the stock VIX also significant. Regarding the change in unemployment, we see the effect from the oil VRP is positive and significant at the one- and three-month horizons, but not the one-year. While the stock VRP has no significant effect on the change in unemployment, we do see the stock RV have an effect at the one-quarter horizon, in addition to that already reported in Table 3. For inflation there is no predictive power beyond the one-month horizon already

Table 5
Multi-horizon predictability with VRP and control variables.

	1-Month	3-Month	12-Months
Oil Returns			
Oil VRP	−0.164 (−2.46)	0.269 (1.77)	0.573 (1.44)
Stock VRP	−0.566 (−0.71)	0.330 (0.45)	0.551 (0.35)
Log DP	0.507 (1.77)	1.122 (1.38)	0.682 (0.70)
TS	0.651 (0.48)	0.153 (0.45)	−0.156 (−0.18)
Default Yield	−0.580 (−0.17)	−0.478 (−0.55)	0.134 (2.50)
Stock Returns			
Oil VRP	0.023 (2.04)	−0.012 (−0.57)	−0.308 (−2.11)
Stock VRP	0.218 (1.76)	0.722 (3.58)	1.279 (3.31)
Log DP	0.301 (2.18)	0.652 (2.49)	0.826 (3.88)
TS	−0.143 (−0.73)	−0.226 (−1.76)	−1.467 (−2.81)
Default Yield	0.423 (1.41)	0.239 (1.62)	1.455 (1.15)
Industrial Production Growth			
Oil VRP	−0.047 (−9.45)	−0.011 (−1.75)	−0.137 (−2.83)
Stock VRP	−0.014 (−0.21)	−0.201 (−0.83)	0.074 (0.53)
Log DP	0.255 (1.87)	0.152 (2.50)	0.178 (2.37)
TS	0.018 (1.71)	0.116 (4.91)	0.193 (4.70)
Default Yield	−0.013 (−0.96)	−0.131 (−1.86)	−0.912 (−0.67)
Change in Unemployment			
Oil VRP	0.392 (8.57)	0.183 (1.80)	−0.048 (−0.76)
Stock VRP	−0.102 (−0.32)	0.956 (0.69)	0.388 (0.36)
Log DP	0.136 (1.37)	−0.389 (−0.01)	−0.135 (−0.13)
TS	0.181 (1.93)	−0.112 (−0.33)	−1.188 (−2.01)
Default Yield	−0.553 (−2.08)	−0.764 (−1.24)	−0.895 (−1.40)
Inflation			
Oil VRP	−0.262 (−3.79)	−0.059 (−0.23)	0.279 (0.14)
Stock VRP	−0.114 (−1.12)	−0.276 (−0.95)	0.737 (1.93)
Log DP	−0.521 (−0.81)	−0.730 (−0.36)	−0.502 (−2.57)
TS	−0.159 (−0.63)	−0.313 (−0.36)	−0.165 (−0.83)
Default Yield	0.110 (2.34)	0.275 (1.86)	0.701 (2.48)
Inflation Expectations Change			
Oil VRP	0.089 (2.07)	0.048 (1.62)	0.708 (1.66)
Stock VRP	−0.501 (−0.54)	0.806 (0.89)	3.531 (2.38)
Log DP	0.678 (1.55)	1.586 (2.47)	0.578 (0.68)
TS	0.789 (0.45)	−0.471 (−0.14)	−3.719 (−2.56)
Default Yield	0.014 (0.20)	−0.303 (−0.24)	1.607 (3.04)

Notes: Entries are the coefficients values (and Newey-West t-statistics) from equation (3), which regresses oil returns (first panel), stock returns (second panel), industrial production growth (third panel), the change in unemployment (fourth panel), inflation (fifth panel) and the change in inflation expectations (sixth panel) against the variables noted in the first column (this includes the log dividend yield, term structure, and default yield, in addition to the oil and stock VRP). The models are estimated over three time horizons as given by the first row.

reported, however, we do observe greater evidence of significant results for the change in inflation expectations. The oil VRP has positive predictive power across all horizons, although the statistical significance weakens over the three-month and one-year periods. The stock VRP also has positive predictive power and, conversely, statistical significance increases with the longer horizons.

Table 5 presents the results for the six predictive variables over the three horizons of $k = 1, 3, 12$ (one-month to one-year) using all predictors, including the oil and stock VRP as well as the log dividend-price ratio, the term structure, and the default yield. The results remain broadly similar to those previously reported, despite the inclusion of the control variables. Oil VRP continues to exhibit significant negative predictive power for oil returns over the one-month horizon that turns positive and wanes in significance at the longer horizons. The oil VRP also continues to positively predict the one-month stock return, with evidence of significant negative predictive power at the one-year horizon. The stock VRP does not exhibit predictive power for the oil return but does positively predict stock returns. Of interest, the stock VRP exhibits strengthening predictive power from the shorter to the longer horizons, while the converse is true with the oil VRP. These results continue to suggest different risk characteristics of the two series, with the effect from the oil VRP impacting quicker but is short-lived compared to the stock VRP. An increase in the oil VRP suggests a continuing downward trend in oil prices and so a negative return, and an immediate fall in stock prices leading to an increase in the subsequent return.

Examining the predictions for the macroeconomic variables, the oil VRP has negative predictive power for output growth and inflation and positive predictive power for the unemployment change and inflationary expectations at the one-month horizon. Over the longer horizons, again predictive power wanes, although remains marginally significant for output growth, unemployment change and inflation expectations. The stock VRP has positive predictive power for inflation and inflation expectations, albeit only at the one-year horizon.

In regard of predictive power arising from the control variables, the log dividend-price ratio exhibits positive predictive power for stock returns over all horizons. For output growth, there is positive and significant predictive power arising from both the log dividend-price ratio and the term structure, albeit only at the 10 % level for the one-month horizon. For the change in unemployment, the default yield at the one-month and the term structure at the one-year horizon exhibit significance, both negatively. For inflation, the default yield indicates positive predictive power across each horizon, while the log dividend-price ratio present negative power at the one-year horizon. The default yield also exhibits positive predictive power for inflation expectations, albeit only at the longest horizon. There is also some evidence of predictive power from the log dividend-price ratio at the 3-month horizon and the term structure at the one-year horizon.

An obvious question with the above results is the extent to which they are impacted by the Covid19 pandemic and resulting market turmoil. As evidenced in Fig. 1, the Covid19 related crash, which we might consider as beginning in March 2020 (the WHO declared a pandemic on 11 March), saw the largest historical falls in the oil and stock markets as well as output. We can see the substantial spikes in both oil and stock VRP's as well as other extreme shifts in inflation, unemployment, the log dividend-price ratio, and the default yield. Although in the context of our sample, this period affects only 12 observations (out of 138), the magnitude of the changes is likely to impact both coefficients and statistical significance.

Table 6 thus, repeats the estimations from Table 5 but in which the sample period ends with 2019. The results of interest broadly remain consistent, although there is some weaker evidence as well as changes in other variables. Notably, the oil VRP continues to exhibit negative predictive power over the one-month horizon for oil returns, industrial production growth, and inflation. Equivalent positive predictive power is reported for stock returns, inflation expectations and the change in unemployment, although only at the weaker 10 % level for the latter. Evidence of longer horizon predictability from the oil VRP is more muted, with the exception of output growth. The stock VRP continues to predict long-horizon stock returns, while the log dividend-price ratio predicts stock returns across all horizons, as well as longer-term behaviour for several other series. The term structure and default yield exhibit varying degrees of predictability for output growth, unemployment, and inflation.

We can consider these results in terms of their implications for risk. Higher risk is associated with a higher value of the oil and stock VRP, the dividend-price ratio (as stock prices fall), a lower term structure and a

Table 6
Multi-horizon predictability with VRP and control variables: Sample Ending 2019.

	1-Month	3-Month	12-Months
	Oil Returns		
Oil VRP	−0.081 (−2.13)	0.424 (1.72)	0.480 (0.63)
Stock VRP	0.295 (0.87)	0.747 (1.27)	0.225 (0.16)
Log DP	0.373 (1.60)	0.797 (1.49)	1.169 (1.27)
TS	0.004 (0.06)	0.082 (0.04)	0.354 (0.54)
Default Yield	−0.362 (−1.32)	−0.655 (−0.90)	0.866 (0.58)
	Stock Returns		
Oil VRP	0.075 (1.98)	−0.115 (−1.77)	−0.395 (−2.98)
Stock VRP	−0.050 (−0.49)	0.374 (1.97)	0.534 (2.83)
Log DP	0.195 (2.11)	0.574 (2.74)	0.985 (4.58)
TS	−0.197 (−0.86)	−0.496 (−0.97)	−0.978 (−0.85)
Default Yield	0.572 (0.53)	0.281 (1.11)	0.927 (0.32)
	Industrial Production Growth		
Oil VRP	−0.023 (−4.41)	−0.061 (−4.39)	−0.137 (−3.19)
Stock VRP	0.048 (3.41)	0.115 (3.47)	0.089 (0.78)
Log DP	0.779 (1.19)	0.429 (2.45)	0.204 (2.27)
TS	0.144 (3.47)	0.480 (4.13)	0.250 (3.310)
Default Yield	−0.220 (−2.42)	−0.692 (−2.80)	−0.783 (−0.57)
	Change in Unemployment		
Oil VRP	0.054 (1.86)	0.092 (1.87)	0.157 (0.51)
Stock VRP	−0.073 (−1.16)	−0.006 (−0.03)	1.578 (1.24)
Log DP	0.462 (0.11)	−0.137 (−1.38)	−1.715 (−2.05)
TS	0.042 (0.27)	−0.553 (−1.08)	−1.925 (−2.37)
Default Yield	−0.049 (−0.87)	−0.786 (0.69)	1.045 (0.95)
	Inflation		
Oil VRP	−0.390 (−2.56)	0.253 (0.39)	0.033 (0.17)
Stock VRP	−0.040 (−0.60)	0.473 (0.29)	0.632 (1.76)
Log DP	−0.427 (−0.64)	−1.569 (−0.91)	−0.386 (−1.21)
TS	−0.020 (−0.79)	−0.079 (−1.34)	−0.049 (−1.04)
Default Yield	0.055 (1.79)	0.194 (0.90)	0.546 (1.87)
	Inflation Expectations Change		
Oil VRP	0.089 (2.42)	0.335 (0.89)	0.658 (0.99)
Stock VRP	0.489 (0.88)	1.354 (1.26)	2.515 (1.85)
Log DP	0.523 (1.27)	1.412 (1.79)	1.309 (1.65)
TS	−0.555 (−0.41)	−1.179 (−0.37)	−0.537 (−2.02)
Default Yield	−0.208 (−0.40)	−0.374 (−0.31)	2.751 (2.77)

Notes: Entries are the coefficients values (and Newey-West t-statistics) from equation (3), which regresses oil returns (first panel), stock returns (second panel), industrial production growth (third panel), the change in unemployment (fourth panel), inflation (fifth panel) and the change in inflation expectations (sixth panel) against the variables noted in the first column (this includes the log dividend yield, term structure, and default yield, in addition to the oil and stock VRP). The models are estimated over three time horizons as given by the first row. The analysis is the same as for Table 5, except the sample period ends with 2019.

higher default yield. For the variables to be predicted over the subsequent period, higher risk would typically result in lower oil returns (oil price continue to fall), higher stock returns (the price falls immediately, and a higher return is required to attract investors), lower output growth, which will be associated with a positive change in the rate of unemployment and lower inflation. Concerning inflation expectations, higher risk would typically be associated with higher such expectations.[13]

The results show that an increase in oil VRP is consistent with subsequently lower oil returns, higher one-month stock returns, lower output growth and inflation and higher unemployment and inflation expectations. Higher stock VRP also leads to higher stock returns, and inflation expectations but also higher inflation. A higher dividend-price ratio follows a similar pattern to the oil VRP, with higher stock returns and inflation expectation and lower output growth and inflation. A lower term structure (higher risk) also leads to lower output growth and, for longer horizons, higher unemployment and inflation expectations. A higher default yield leads to higher inflation across each period and, at the one-year horizon, inflation expectations. The difference in the nature of the results for the two inflation series arise as we measure inflation as the *k*-difference in CPI, whereas inflation expectations are based on 10-year Treasury bonds and thus, capturing longer-term behaviour. For example, a rise in oil market risk is likely to have an immediate negative impact on the macroeconomy, while signalling higher future oil prices and inflation.

Of key interest, we see a difference between the oil and stock VRP series. While, perhaps unsurprisingly, oil VRP predicts oil returns, it also predicts stock returns. In contrast, stock VRP only has predictive power for stocks. Moreover, oil VRP has greater predictive power at the shorter (one-month) horizon, with stock VRP exhibiting a higher degree of predictive power at the three- and twelve-month horizons.[14] This suggests that movements in oil VRP have a more immediate impact on markets, while the effects arising from stock VRP develop over a longer period. This is equally reflected in the macro-variables where oil VRP has a significant predictive effect at the one-month horizon, while stock VRP has predictive power at the one-year horizon (only for output growth does the oil VRP have predictive power across all horizons).

In understanding the different effects that arise from the two VRP series, we consider the nature of the assets and the impacts that arise from their price changes. Oil price changes, which reflect current and expected global demand and supply as well as geopolitical tensions, exhibit substantial abrupt changes, which have a more immediate impact on the economy given both its commercial and retail uses. This is evidenced in the summary statistics from Table 1, as well as the graphs in Fig. 1, in which there are a greater number of extreme values associated with oil returns compared to stock returns. For example, within the sample, there are sixteen months in which the oil price fell by 10 % or more, compared to two months for stock returns.[15] Reflecting this, we see the average oil VRP noticeably greater than that of the stock VRP, as well as exhibiting a larger maximum value. Changes in stock market prices and risk reflect expectations regarding future economic conditions, with the discounted future cash flow representing our main approach to stock pricing. Although a stock index reflects a single asset class, it represents the ability of companies across a range of market sectors to generate future profits. This, therefore, incorporates longer-term considerations of economic risk.[16]

Table 7
Out-of-sample mean squared error values.

	Constant Only	OIL VRP	ALL	ALL XC OIL VRP
Oil Returns	2.0884	1.7912	1.7861	2.0629
Stock Returns	1.3376	0.6536	1.0929	1.2807
IP Growth	3.9835	2.7026	2.5457	3.4969
Change in Une	2.1814	1.2097	1.1827	1.8387
Inflation	0.0506	0.0479	0.0435	0.0429
Inflation Expect. Ch.	0.1488	0.1215	0.4476	0.5112

Notes: Entries are the mean squared error values from the out-of-sample forecasts for four different forecast models based on equation (3), and listed in the first row. The Constant Only model contains no predictor variables, OIL VRP contains only the oil VRP series, ALL contains all the predictor variables (oil VRP, stock VRP, log dividend yield, term structure and default yield). ALL XC OIL VRP contains all the same variables as ALL except the oil VRP series. The series to be forecast are given in the first column.

4.1. Out-of-sample forecasting

To further consider whether oil VRP has a significant impact on our variables, we consider a small out-of-sample forecast exercise. The predictive equation (3) is re-estimated in a recursive fashion beginning with the first five years (60 observations) of the sample, where the end of sample is extended by one observation at each iteration. From this, one-step ahead forecasts are generated with each recursion. To evaluate these forecasts, we compute both the mean squared error (MSE), reported in Table 7, and calculate the squared error in a cumulative manner, depicted in Fig. 2. Moreover, we do this by estimating four variants of equation (3). Specifically, a constant only model, which serves as a baseline, a model that contains only the oil VRP, a model with all the predictor variables as noted in Table 6 (oil VRP, stock VRP, log dividend yield, term structure and default yield), and a model that contains all the predictor variables except the oil VRP. For clarity, the mean squared error is given as:

$$MSE = \left(\sum_{t=1}^{\tau} \left(y_t - y_t^f \right)^2 \right) \Big/ \tau \qquad (4)$$

where τ is the forecast sample size, y_t is the observed values of the series to be forecast and y_t^f represents the forecast series.

The MSE results in Table 7 demonstrate that the forecasts that include the predictor variables outperform the constant only model for all six variables of interest. The 'ALL' model achieves the lowest MSE for three of the variables (oil returns, industrial production growth, and the change in unemployment), while the 'oil VRP' only model performs the best for two of the remaining series (stock returns and inflation expectations). Of notable interest, the 'oil VRP' only model outperforms the 'ALL except the oil VRP' for all series, supporting the view that the oil VRP carries information content. The sole exception to this is for inflation, where the 'ALL except the oil VRP' is preferred.

The cumulative MSE values in Fig. 2 are, perhaps, of greater interest. For each of the series, the difference in forecast performance between the four different models is relatively small prior to the Covid19 pandemic period. This is most clearly seen for the output growth and change in unemployment series, and to a lesser extent the oil return forecasts. In contrast, after the start of the pandemic, there are notable differences in forecast performance. That all forecasts perform worse

[13] It is acknowledged that in respect of inflation and inflation expectations, there is not a linear relation with risk. Both higher and lower inflation can be consistent with higher risk. Higher inflation is likely to indicate future policy action leading to an economic slowdown and we attribute this effect to that observed for inflation expectations. Lower inflation occurs when an economy is already in a downturn, and we attribute this effect to inflation itself. However, opposite views are possible and acknowledged.

[14] The log dividend-price ratio, which also captures stock market risk, exhibits long-horizon predictive power for stock returns and the macroeconomic series.

[15] There are also eleven months in which the oil price rose by 10 % or more, with none for the stock return.

[16] As noted, the impact of oil on the macroeconomy is a long-standing area of research (see, for example, Hamilton, 1983, 1996; Barsky and Kilian, 2004; Blanchard and Gali, 2007).

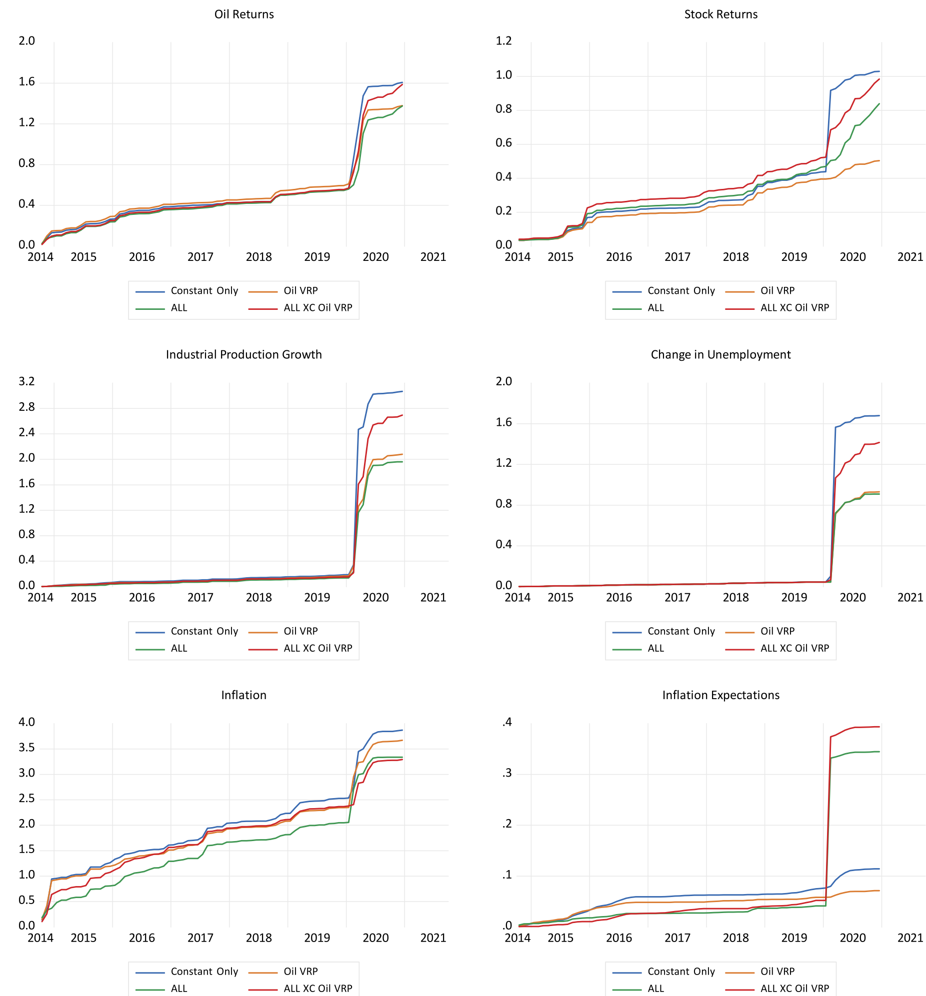

Fig. 2. Cumulative MSE Values
Notes: The plots are cumulative squared errors obtained over the out-of-sample forecast period for the four different forecast models based on equation (3), i.e., the Constant Only model that contains no predictor variables, OIL VRP contains only the oil VRP series, ALL contains all the predictor variables (oil VRP, stock VRP, log dividend yield, term structure and default yield). ALL XC OIL VRP contains all the same variables as ALL except the oil VRP series. The series to be forecast are given in the individual headings, oil returns (first graph), stock returns (second graph), industrial production growth (third graph), the change in unemployment (fourth graph), inflation (fifth graph) and the change in inflation expectations (sixth graph).

given the break associated with Covid19 is not unexpected due to its unpredictable nature. However, it is clear that those models that incorporate predictor variables that are also affected by Covid19, perform better than the constant only model, with the only exception being forecasts for the inflation expectations series.

5. Summary and conclusion

Research has increasingly sought to find variables that represent investor risk preferences. This paper examines the ability of the oil variance risk premium (VRP) to predict both financial and macroeconomic variables and contrasts its performance with the previously identified stock VRP. The VRP measure incorporates the ex-ante implied volatility and the ex-post realised volatility measures, and it represents investor risk aversion.

Using monthly data over the period from 2009 to 2021, we examine the predictive ability of the oil and stock VRP for oil and stock returns, as well as output growth, the change in unemployment and two measures relating to inflation. We consider predictive power over one-, three- and twelve-month horizons and include several control variables used within the literature. Our primary interest is whether oil VRP adds predictive power over that previously reported for stock VRP and whether its characteristics differ. Our expectation is that higher oil VRP would be consistent with increased oil market risk, which would have not only a negative impact on oil returns themselves but also the wider economy.

Our results reveal that the oil VRP has negative predictive power for oil returns, output growth and inflation and positive predictive power for stock returns, the change in unemployment, and inflation expectations. This is consistent with our view that a rise in oil VRP is synonymous with higher risk. A higher oil VRP sees a sustained fall in the oil market, an immediate fall in the stock market that requires an increased expected return and weakening macroeconomic conditions with a fall in output and inflation and higher unemployment. Inflation expectations also arise, which likewise indicate an increase in economic risk (inflation expectations are also based on a longer-term government bond). Our results also reveal that this pattern of predictive power wanes beyond the one-month horizon, with only more limited evidence of a significant relation at the three- and twelve-month horizons. In contrast, stock VRP does not exhibit predictive power at the one-month horizon but is more likely to do so over the longer periods. This suggests different information content arising from the oil and stock VRP series, with oil risk representing a more immediate effect and stock risk indicating a longer-term effect.

The results here suggest different risk profiles for the oil and stock markets, with a change in oil VRP leading to a market impact in the succeeding period before waning, while a change in stock VRP carries longer term information but is less likely affect the following period. This arises as change in the oil market has an immediate effect on both firm and households, for example, in term of energy prices, while changes in the stock market reflects longer-term considerations regarding future economic performance. As such, these results should be of interest to both market participants and policymakers.

CRediT authorship contribution statement

David G. McMillan: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Salem Adel Ziadat:** Conceptualization, Data curation, Investigation, Writing – review & editing, Methodology.

Declaration of competing interest

None.

Data availability

The authors do not have permission to share data.

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