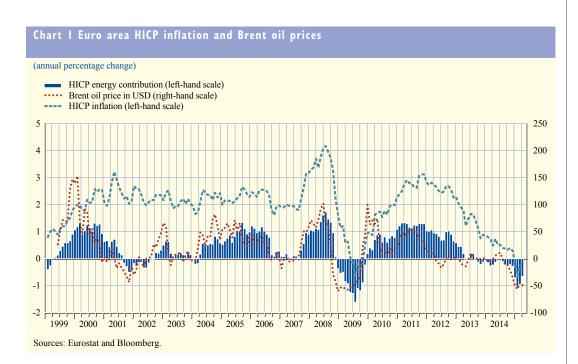
# FORECASTING THE PRICE OF OIL

Oil price forecasts are a crucial input into macroeconomic projections, in particular owing to the impact that oil prices have on inflation and output and, hence, on monetary policy. Using futures to forecast oil prices provides a transparent and simple tool which is easy to communicate. However, futures are an imperfect reflection of market expectations and have contributed to large forecast errors in HICP inflation in the past. This article presents an approach for checking the risks surrounding futures-based forecasts against a model combination which produces lower forecast errors and is more robust to changes in oil price dynamics.

# I INTRODUCTION

**Future developments in oil prices tend to be an important conditioning factor in macroeconomic projections for output and inflation.** With regard to inflation, the path of oil prices determines both the direct impact via the prices of energy products which are directly consumed by households, such as transport fuels, and the indirect impact via the production costs for final goods and services. Historically, much of the volatility in euro area HICP inflation has stemmed from changes in the energy component (see Chart 1). With regard to output, the impact of oil price developments essentially derives from the associated changes in real disposable income for households and companies and their knock-on effects for consumption and investment spending.

Recent developments in oil prices have highlighted the difficulty in projecting such developments. While oil prices were broadly stable from 2011 to mid-2014, they declined by more than 50% from end-June 2014 to mid-January 2015 owing to an oversupplied oil market, with robust increases in North American shale oil production and sluggish oil demand growth. Since then, oil prices have increased by around 40%, mostly on account of some indications of a possible slowdown in US oil supply and expectations of higher oil demand. However, the near-term outlook remains highly uncertain.



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The performance of projections in terms of accuracy or bias critically hinges on the ability to anticipate the future path of oil prices. In the Eurosystem/ECB staff macroeconomic projections, as in those of many other central banks and international organisations, the prices in oil futures markets are used as technical assumptions to reflect expectations about future oil price developments. However, large oil price forecast errors have been made using such futures-based assumptions. Reviews of the Eurosystem/ECB staff projections have shown that the projection bias for the HICP in the period since 1999 would have been significantly reduced if oil price movements had been better anticipated. Indeed, a large part of the underestimation of euro area HICP inflation in this period stemmed from this source.

Against this background, this article discusses the general difficulties in forecasting oil prices (Section 2), elaborates on the forecast properties of oil futures (Section 3), provides an overview of alternative forecasting methods (Section 4), and introduces a newly developed forecast combination method for Brent oil prices (Section 5).

# 2 THE DIFFICULTY IN FORECASTING OIL PRICES

Although oil prices are predictable to some extent, accurately forecasting them is a challenging task. Oil prices are predictable as oil is a physical commodity, the price of which is largely determined by oil fundamentals and in particular by global economic activity. Nevertheless, finding an accurate tool for oil price forecasting is complicated by the fact that oil market dynamics tend to vary substantially over time. This section discusses the determinants of oil price movements and explains the challenges that time variation in oil price behaviour poses for oil price forecasting.

Depending on the driving factor, oil prices can behave very differently over time. Oil prices have evolved in very different ways over time, varying between being stable, trending upwards and falling abruptly (see Chart 2). Major movements in oil prices can largely be explained by changes in oil supply, oil demand and oil inventories. Taking a historical perspective, the major oil shocks of the 1970s and 1980s were caused by severe disruptions on the supply side.<sup>2</sup> Having been broadly stable for most of the 1990s, oil prices increased strongly from 2003 onwards owing to strong growth in global economic activity driven by emerging market economies, and in particular China. This demand-driven rise in oil prices was only interrupted in 2008 by the global financial crisis, which caused oil prices to drop by about 70% over a few months as a result of falling global economic activity that triggered a sharp slowdown in oil demand growth in advanced economies in particular. Following a rapid recovery from 2009 onwards, oil prices were broadly stable for about four years owing to slowing oil demand growth and the rise in shale oil production in North America, which were broadly offset by supply-side concerns related to geopolitical tensions in the Middle East and, to some extent, Russia. At the same time, continued gains in energy efficiency and increased substitution with other energy sources contributed to restraining oil demand growth. More recently, oil prices fell steeply as robust increases in North American shale oil production together with sluggish oil demand growth, particularly in China, caused the oil market to be oversupplied. Markets reassessed their outlook for the oil market in the light of receding geopolitical risks, as heightened geopolitical uncertainty in major oil-producing countries did not affect global oil supply.

<sup>1</sup> Brent crude oil prices are used as they are the leading global price benchmark for sweet light crude oil (given that Brent prices are used for the majority of internationally traded crude oil). In addition, Brent crude oil is mostly destined for European markets and therefore captures well the oil price dynamics relevant for the euro area, while West Texas Intermediate (WTI) better reflects the US market.

<sup>2</sup> See, for example, Hamilton, J.D., "Causes and Consequences of the Oil Shock of 2007-08", Brookings Papers on Economic Activity, Vol. 40 (1), 2009, pp. 215-283.

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(in USD per barrel; US CPI index as deflator, 1982-84=100 (left-hand side), one standard deviation (right-hand side))

- oil price volatility (right-hand scale) real oil price (left-hand scale)
- nominal oil price (left-hand scale)



Sources: Energy Information Administration and Federal Reserve Economic Data. Notes: Monthly data; the Brent oil price in USD per barrel has been backcasted with the growth rate of the refiner's acquisition cost of imported crude oil up to May 1987 and deflated using the US Consumer Price Index. Oil price volatility is measured as the six-month rolling standard deviation of the nominal oil price

Despite the oversupplied oil market, OPEC decided not to lower oil production at its meeting in November 2014. Historically, Saudi Arabia has tended to behave as the "swing producer" in the oil market, stabilising oil prices by reducing its output when oil prices decline and increasing it when prices go up.3 Its changed strategy in November exacerbated the oil price drop, as its decision not to react was interpreted as a move to maintain market share given the rise in North American shale oil. In sum, it is clear that the dynamics in the oil market can differ substantially depending on the driving factor of oil price movements. In addition to movements in oil supply and demand, the level of oil inventories and changes in that level also crucially determine oil price dynamics.

In addition, oil price volatility seems to have increased over time (see Chart 2). There is empirical evidence that variations in the price elasticities of oil demand and supply create periods of elevated oil price volatility.<sup>4</sup> Other studies relate part of this higher oil price volatility to the increased use of oil as a financial asset. The active management of oil price assets in futures markets since the early 2000s, also referred to as the "financialisation" of the oil market, might have caused oil prices to react more quickly to macroeconomic news that is reflected in the prices of assets such as stocks and in exchange rates.5

Changing oil market dynamics and increased oil price volatility have several implications for oil price forecasting. First, as oil is a physical commodity of which the price is largely determined by economic fundamentals, including data on these economic determinants helps in forecasting oil prices more accurately. Data limitations, with respect to fluctuations in global oil inventories, for example, nevertheless make it more difficult to accurately capture movements in oil fundamentals.<sup>6</sup> In addition, as oil is also increasingly used as a financial asset, spot oil prices tend

However, in a few instances such as in 1986, Saudi Arabia decided not to lower oil production as this strategy was deemed to be counterproductive in an environment of sluggish demand growth, weak cartel discipline and strong non-OPEC production growth.

See, for example, Baumeister, C. and Peersman, G., "The role of time-varying price elasticities in accounting for volatility changes in the crude oil market", Journal of Applied Econometrics, Vol. 28(7), 2013, pp. 1087-1109.

See, for example, Fratzscher, M., Schneider, D. and Van Robays, I., "Oil prices, exchange rates and asset prices", Working Paper Series, No 1689, ECB, 2014.

In 2011 the G20 recognised the importance of transparency in the oil market for world economic growth and expressed support for the improvement of data availability on oil production, consumption, refining and stock levels in the context of the Joint Oil Data Initiative.

to reflect changes in the macroeconomic environment more rapidly. This might cause increased oil price volatility in the short run, making it more difficult to forecast oil prices over these horizons. Second, as oil market dynamics tend to change substantially over time (depending on the driving factor), there might be considerable instability in the performance of an individual forecast method that only captures a specific behaviour of oil prices. As a consequence, combining different forecasts that each capture a specific behaviour of oil prices might help in addressing time variation in the performance of individual forecast models caused by changing oil market dynamics. The next sections discuss the limitations of the futures-based oil price forecast and alternative approaches to oil price forecasting, while Section 5 describes a forecast combination approach for Brent oil prices in more detail.

# 3 FUTURES AS A REFLECTION OF EXPECTED OIL PRICE MOVEMENTS

Oil price futures are frequently used as the baseline for oil price assumptions in economic projections. They are used, for example, in the Eurosystem/ECB staff macroeconomic projections and in the projections of many other central banks and international institutions. The main reason for using futures as a baseline for oil price assumptions is that they provide a simple and transparent method which is easy to communicate.

However, oil price assumptions based on futures yield large forecast errors. Table 1 shows the mean absolute error (MAE) and the root mean squared error (RMSE) of the Eurosystem/ECB projection assumptions for nominal oil prices four and eight quarters ahead for the period 2005 to 2014. The MAE suggests that on average over this period, the projections four and eight quarters ahead deviated by about 17% and 20% respectively. The higher RMSE values show that the MAE masks important variations in the projection performance over time. These errors have a significant impact on inflation projections. While estimates of the impact of a 10% increase in oil prices on HICP inflation are surrounded by uncertainty, they tend to be in the range of 0.2-0.3 percentage point in the first year after the shock, and an additional 0.1-0.2 percentage point in the second year. This effect has been found to depend on the level of oil prices, with a stronger impact being measured when oil prices are at an elevated level. In addition, futures had a negative forecast bias (see the third column of Table 1), indicating that oil prices tend to turn out higher on average than futures prices would suggest.

The main reason for the large forecast errors of futures is that the futures curve is usually flat and downward sloping owing to the specific nature of oil as a physical and storable commodity. As a result, the wedge between futures and spot prices, which defines the slope of the futures curve, increases with the risk-free rate<sup>8</sup>, the risk premium and storage costs and decreases with the convenience yield. While the first two factors are present for any asset traded in the spot and

Table I Average projection errors for oil prices										
(Q1 2005 to Q4 2014)										
	Mean absolute error	Root mean squared error	Bias							
Four quarters ahead	16.9	24.3	-1.6							
Eight quarters ahead	19.9	24.4	-6.9							
Source: ECB calculations.										

- 7 See "Energy markets and the euro area macroeconomy", Occasional Paper Series, No 113, ECB, June 2010.
- 8 The risk-free rate is the opportunity cost of buying a specific asset.

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futures market, the latter two are typical for oil as a storable commodity with limited inventories. The convenience yield is the benefit of holding inventories and tends to be larger than the other components driving the wedge between futures and spot prices. As a result, spot prices are typically higher than futures prices, defining a downward slope which is also known as backwardation. The reason for this is that when oil markets are tight, demand for inventories at the spot price is high, bringing spot prices up relative to futures prices. However, the futures curve can also be upward sloping, a situation also known as contango. This situation occurred in the recent past owing to ample oil supply combined with a high level of inventories, and it also occurred before and after the global recession (see Chart 3). However, since 1999 the futures curve has been downward sloping for about 70% of the time.

In addition to following a generally downward sloping path, futures curves are typically rather flat owing to the arbitrage between spot and futures prices. Futures therefore tend to predict oil prices quite well in times of stable prices, while forecast errors are high when oil prices are volatile. Chart 4 shows that for 2012 and 2013, futures for four and eight quarters ahead provided



fairly accurate projections as oil prices were relatively stable. However, forecast errors were large in periods of falling and rising oil prices, such as around the period of the global financial crisis and during the most recent episode of falling oil prices.

Overall, oil price futures are an imperfect reflection of market expectations owing to the fact that arbitrage opportunities lead to a rather flat profile of the futures curve and the convenience yield typically results in a downward sloping futures curve. Neither of these features are directly related to market expectations of future oil price developments. While changes in the slope of the futures curve can provide some information about market expectations regarding current and expected oil demand and supply fundamentals, overall the futures curve has not proved to be a good predictor of oil prices.

#### 4 ALTERNATIVE APPROACHES TO OIL PRICE FORECASTING

The literature on oil price forecasting has grown rapidly over the past few years, partly as a response to the shortcomings of futures-based predictions. These alternative forecast approaches can be divided into three broad categories: (i) market-based and statistical approaches, (ii) approaches based on economic theory, and (iii) model forecast combinations. This section briefly discusses selected models in each of these categories.

First, market-based indices or statistical methods have the advantage of being simple and transparent forecasting tools, but generally do not manage to consistently outperform other methods. With regard to market-based forecasts, an alternative to futures are "risk-adjusted" futures, which attempt to correct the negative bias of the futures-based forecast by adjusting it for a risk premium. This risk premium, which affects the spread between the oil futures and the spot price, varies over time and is related to the business cycle. The risk-adjusted futures are found to outperform futures particularly at longer horizons beyond six months. With regard to other statistical approaches, alternative methods of forecasting oil prices include the random walk (which assumes the future oil price to be equal to the price today), the random walk with drift (which assumes oil prices to grow at a specific rate), and simple autoregressive moving average models. However, none of these simple approaches tend to outperform other methods such as futures-based forecasting in a robust manner across forecast horizons and over time.

Second, forecast models that include data on economic determinants tend to forecast more accurately than simple approaches. Such models are based on the observation that oil prices are largely determined by movements in economic variables such as oil demand and supply, global economic growth and interest rates. As such, to the extent that these economic variables contain information on future oil price developments, including them in forecasting models tends to improve the oil price prediction. There are many possible forecast approaches that are based on economic theory, ranging from simple regressions to more complex multi-variable models.

For example, including data on non-oil commodities, oil supply and global economic activity helps in more accurately forecasting oil prices over specific forecast horizons and time periods. Based on the intuition that movements in non-oil commodities reflect movements in global commodity demand, forecasting oil prices using the recent growth rate of non-oil commodity prices appears successful in predicting oil prices in the short run. Simple regressions

<sup>9</sup> See Pagano, P. and Pisani, M., "Risk-Adjusted Forecasts of Oil Prices", The B.E. Journal of Macroeconomics, Vol. 9(1), 2009.

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linking the oil price prediction to changes in the risk-free interest rate and exchange rates of major commodity exporters have also been explored in the literature, among many other approaches. Although they are more highly parameterised, vector autoregression (VAR) models that include data on oil production, inventories and global economic activity have proved to forecast oil prices more accurately than the random walk or futures over specific time periods, mainly in the short run. Using Bayesian techniques to estimate the VAR model can further improve the forecast accuracy of these VAR-based projections. Finally, structural models of the oil market can also be useful for oil price forecasting. For example, it has been shown that a general equilibrium model consisting of oil-exporting and importing regions that models long-term oil price dynamics can improve the forecast relative to futures in periods of rising oil prices, benefiting from, among other features, the inclusion in the model of a detailed structure of the supply side of the oil market and the assumption that oil prices follow a trend. In the model of a detailed structure of the supply side of the oil market and the assumption that oil prices follow a trend. In the model of a detailed structure of the supply side of the oil market and the assumption that oil prices follow a trend. In the model of a detailed structure of the supply side of the oil market and the assumption that oil prices follow a trend. In the model of a detailed structure of the supply side of the oil market and the assumption that oil prices follow a trend.

However, the general problem with individual forecast methods is that their forecast performance tends to be very unstable over time given the frequent changes in oil market dynamics. As already indicated in Section 2, this is because many models capture only a specific behaviour of oil prices over a particular horizon, and oil price dynamics tend to change considerably over time depending on the driving factor. For example, VAR models which include data on economic activity and oil fundamentals tend to result in accurate forecasts of short-run oil price movements that are driven by changes in global economic activity. However, they quickly lose their accuracy when other factors play a larger role and at longer forecast horizons.

By pooling projections from different forecast approaches, forecast model combinations tend to offer a more accurate forecast that is also more stable over time. These types of forecast model are based on the recognition of the instability in the performance of individual methods. It is well established in the forecast combination literature that it is helpful to combine individual forecasts that have diverse forecast properties in order to find a projection which is more robust vis-à-vis structural breaks in the variable to be forecasted. Given the frequent changes in oil market dynamics, a model forecast combination has proved to perform well in oil price forecasting.

# 5 A FORECAST COMBINATION FOR BRENT OIL PRICES

This section introduces a forecast combination which has been newly developed at the ECB for predicting Brent oil prices and investigates its performance in the context of the Eurosystem/ ECB staff macroeconomic projections. This model combination<sup>15</sup> is constructed as an equally weighted average of the individual projections generated by (i) futures, which provide the current baseline in the Eurosystem/ECB staff macroeconomic projections; (ii) "risk-adjusted" futures, which provide a statistical model that aims to correct the forecast error of futures by adjusting

<sup>10</sup> For an overview, see Alquist, R., Kilian, L. and Vigfusson, R.J., "Forecasting the Price of Oil", in Elliott, G. and Timmermann, A. (eds.), *Handbook of Economic Forecasting*, Vol. 2, 2013, pp. 427-507

<sup>11</sup> See Kilian, L. and Baumeister, C., "Real-Time Forecasts of the Real Price of Oil", *Journal of Business & Economic Statistics*, Vol. 30(2), April 2012, pp. 326-336.

<sup>12</sup> See Nakov, A. and Nuño, G., "Saudi Arabia and the Oil Market", *The Economic Journal*, Vol. 132, 2013, pp. 1333-1362, and Manescu, C. and Van Robays, I., "Forecasting the Brent oil price: addressing time-variation in forecast performance", *Working Paper Series*, No 1735, ECB, 2014.

<sup>13</sup> See, for example, Timmermann, A., "Forecast Combinations", Handbook of Economic Forecasting, Vol. 1, 2006, pp. 135-196.

<sup>14</sup> For WTI oil prices, see for example Baumeister, C., Kilian, L. and Lee, T.K., "Are there gains from pooling real-time oil price forecasts?", *Energy Economics*, Vol. 46, December 2014, pp. 33-43. For Brent oil prices, see Manescu, C. and Van Robays, I., "Forecasting the Brent oil price: addressing time-variation in forecast performance", *Working Paper Series*, No 1735, ECB, 2014.

<sup>15</sup> The model combination is based on the findings of Manescu, C. and Van Robays, I., "Forecasting the Brent oil price: addressing time-variation in forecast performance", Working Paper Series, No 1735, ECB, 2014.

for a time-varying risk premium linked to US economic activity; (iii) a Bayesian VAR (BVAR) model, which is an empirical model based on data related to oil fundamentals (oil production and oil inventories) and global economic activity; and (iv) a dynamic stochastic general equilibrium (DSGE) model, which is a theoretical model of the long-term dynamics in the oil market (including data on global and Saudi Arabian oil production and global economic activity) in which oil prices are assumed to follow a trend.

The advantages of using this specific combination are shown in a real-time and out-of-sample evaluation exercise that follows the set-up of the Eurosystem/ECB staff macroeconomic projections (see Box 1 for details on the set-up of the evaluation exercise). The results demonstrate that also when following the set-up of the projections, the four-model forecast combination manages to improve the forecast accuracy over futures on average, reduce the negative forecast bias and, at the same time, offer a more robust forecast performance over time, justifying the use of the model combination as an alternative to the oil price forecast based on futures. In addition, as already mentioned in the previous section, individual models can perform quite differently depending on the behaviour of oil prices, which is why the performance of the individual models is examined not only for the 1995-2014 period as a whole, but also for sub-periods (see Table 2).

# Box

# THE SET-UP OF THE FORECAST PERFORMANCE EVALUATION EXERCISE

This box provides an overview of how the forecast performance of the different models and of the model combination<sup>1</sup> is evaluated.

The evaluation focuses on real oil prices in US dollars and is conducted in real time and out of sample, at the cut-off dates for the projections using data from the first quarter of 1995 to the last quarter of 2014.² For the estimation of BVAR model parameters, data back to January 1973 are used. When monthly data are not available over the full estimation sample or are only available with delay, the series are backcast or nowcast in a way largely similar to the approach of Baumeister and Kilian.³ For the risk-adjusted futures, monthly futures contract data from January 1990 onwards are used.⁴ All models are re-estimated at each point in time in the evaluation exercise, except for the DSGE model, the parameters of which are calibrated.⁵ The forecast evaluation is applied to quarterly forecasts, up to 11 quarters ahead, which are obtained by aggregating the monthly forecasts. Real rather than nominal oil prices are used for two reasons. First, two of the models included in the combination, i.e. the BVAR and the

<sup>1</sup> The model combination and the different models that are included in the combination are those proposed in Manescu, C. and Van Robays, I., "Forecasting the Brent oil price: addressing time-variation in forecast performance", Working Paper Series, No 1735, ECB, 2014.

<sup>2</sup> Prior to November 1998, the cut-off dates are artificially generated following the pattern of later cut-off dates.

<sup>3</sup> Baumeister, C. and Kilian, L., "Real-Time Forecasts of the Real Price of Oil", Journal of Business & Economic Statistics, Vol. 30(2), April 2012, pp. 326-336.

<sup>4</sup> For futures contracts with longer maturities, the sample is even shorter, depending on data availability. Where possible, data series have been reconstructed backwards on the basis of growth rates of WTI futures with matching maturity.

<sup>5</sup> The DSGE parameters are calibrated using data available over the period from 1973 to 2009. The calibrated parameters refer to long-term trends and relationships based on economic theory which can be assumed not to change frequently over time.

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DSGE, already produce forecasts of real oil prices.<sup>6</sup> Second, in practice, given the volatility of oil prices compared with the volatility of inflation, the difference between a focus on real prices and a focus on nominal prices should not be great.<sup>7</sup> Two criteria are used as quantifiers in the evaluation, i.e. the mean squared prediction error (MSPE) and the forecast bias, and the evaluation is applied to different sub-samples such that the stability of the performance over time can also be evaluated. The MSPE is a commonly used measure of forecasting performance. In addition, it is important that policy-makers are aware of the magnitude of the bias inherent in the projections and the probability of making large forecast errors.

- 6 Forecasting nominal oil prices would add more parameter uncertainty and probably worsen the performance of these two models. As the futures and risk-adjusted futures models retrieve forecasts of nominal oil prices, the approach for the evaluation exercise is to deflate these projections with the expected US CPI, which is forecasted using a three-month moving average process.
- 7 When the forecast evaluation is conducted again using nominal oil prices, the four-model combination performs broadly the same

The performance of the BVAR stands out during periods of stable and moderately increasing oil prices. Over the period from 1995 to 2001, when oil prices were initially broadly stable and then rose between 1999 and 2001, the BVAR is more accurate than futures for both short-term and longer-term forecast horizons, while the other models are more accurate than futures only in exceptional cases. The improvements vis-à-vis the futures-based model reach up to 24%, but they are not always statistically significant.

Among the models included in the combination, the DSGE performs remarkably well during periods of increasing oil prices. For example, during the period 2002-07, the other three models used in the combination broadly outperform futures on the basis of the mean squared prediction error (MSPE) criterion, emphasising the disadvantage of futures forecasts owing to their generally downward sloping curve. Of the three, however, the DSGE performs best, with a 24% improvement for the horizon four quarters ahead, 51% for eight quarters ahead, and 67% for eleven quarters ahead (see Table 2, panel B). All these improvements are statistically significant. The success of the

Table 2 M	lean square	d predicti	on errors c	of real oil pi	rice forecas	sts relative	to future	S
Panel A								
Selected	1995-2014				1995-2001			
horizon (quarters)	Adjusted futures	BVAR	DSGE	Four-model combination	Adjusted futures	BVAR	DSGE	Four-model combination
1	1.01	1.19	1.88 *	1.18 *	0.99	0.94	1.37	1.02
2	1.03	1.06	1.33	1.04	1.07	0.82	1.47	0.96
4	0.95	0.92	0.93	0.89 *	1.11	0.88 *	1.63	0.87
8	0.78	0.98	0.95	0.76 *	1.27	1.08	3.27 *	0.84
11	0.90	0.90	0.78	0.69 *	1.26	0.76	3.88 *	0.58 *
Panel B								
Selected	2002-2007			2008-2014				
horizon	Adjusted	BVAR	DSGE	Four-model	Adjusted	BVAR	DSGE	Four-model
(quarters)	futures			combination	futures			combination
1	1.02	1.00	1.19	0.99	1.00	1.27	2.15 *	1.26 *
2	0.94	0.94	0.83	0.87 *	1.04	1.11	1.43	1.09 *
4	0.81	0.82 *	0.76 *	0.82 *	1.02	0.99	0.95	0.94
8	0.88	0.73 *	0.49 *	0.72 *	0.50	1.36 *	1.15 *	0.82 *
11	1.11	0.66 *	0.33 *	0.70 *	0.25	1.58 *	1.11	0.69

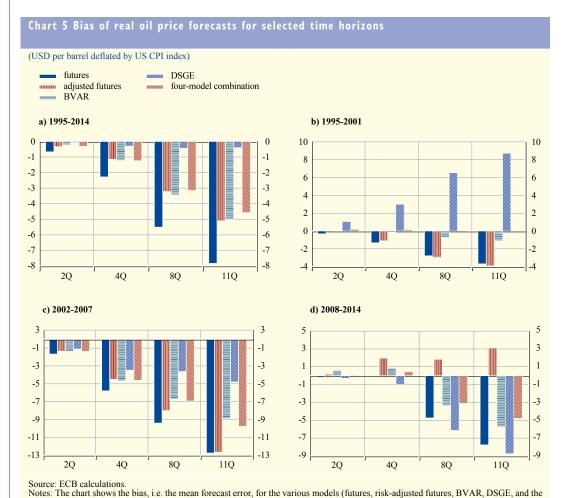
Source: ECB calculations.

Notes: The table shows the mean squared prediction errors (MSPE) relative to futures for the other models: risk-adjusted futures ("adjusted futures"), BVAR, DSGE and the four-model forecast combination (the latter in blue). A value lower than one means that the method outperforms futures on average over the sample period indicated at the top of each table section. The numbers in bold indicate an improvement relative to futures.\* indicates that the results are statistically significant according to at least one of the following tests: Diebold Mariano, White and Hansen.

DSGE model during this period is partly due to the assumption that oil prices follow a trend. Nevertheless, this compensates for the very poor performance of the DSGE model in the other sub-samples.

During the more recent 2008-14 period, when oil prices were initially very volatile and then stabilised, the risk-adjusted futures model is very successful in forecasting at longer time horizons, while futures are successful at shorter horizons. From the second year onwards, the risk-adjusted futures model clearly outperforms futures. Moreover, the MSPE improvement is very high: 50% for the horizon eight quarters ahead and 75% for eleven quarters ahead. <sup>16</sup> Futures seem to perform well during this period for shorter time horizons, as demonstrated by the MSPE values (see Table 2, panel B). This assessment is also supported by the low forecast bias situated around zero for this particular period and these particular horizons.

All models included in the combination manage to improve on the significant negative forecast bias of futures, which is mainly due to the backwardation characteristic of the oil futures curve. This seems to apply in particular to the DSGE model, which has an average forecast



four-model forecast combination) for the main sample and different sub-samples at selected forecast horizons (two, four, eight and eleven quarters ahead).

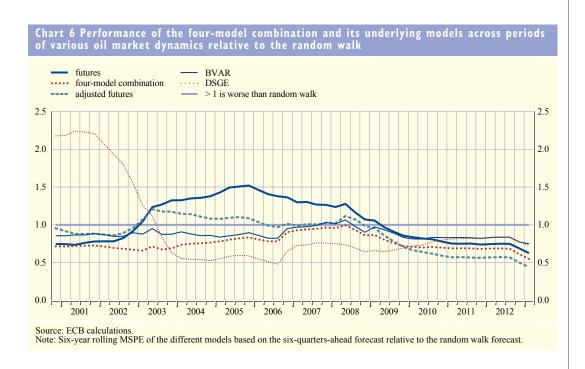
<sup>16</sup> It should be noted that, for this period, the estimation sample – which for the risk-adjusted futures model only begins in January 1990 – is considerably larger, with up to 156 observations, which is twice the estimation sample size for the 1995-2001 period. For a model that is mainly based on ordinary least squares, this can result in greater consistency and robustness in the results.

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bias of around zero over the whole evaluation period (see Chart 5). However, caution is needed in interpreting this finding, as this low value hides a high positive bias during the period from 1995 to 2001 that is balanced out by a large negative bias in the subsequent periods. This notwithstanding, during periods of increasing oil prices, i.e. 2002 to 2007, the DSGE has the lowest bias. As also suggested by the MSPE, the BVAR has the lowest bias in times of stable and locally increasing oil prices, while the risk-adjusted futures model has the lowest bias in times of decreasing and stable oil prices, but only for longer time horizons, i.e. seven to eleven quarters ahead.

It is thus clear that the different models perform well in specific periods and over specific horizons. As such, owing to these clear differences in forecast properties, combining the models offers substantial gains in forecast accuracy, both over time and across forecast horizons. Over the whole period from 1995 to 2014, the four-model forecast combination is more accurate than futures on average by 11%, 24% and 31% at forecast horizons four, eight and eleven quarters ahead respectively (see Table 2). At the same time, it reduces the negative forecast bias of futures on average by 46%, 43% and 42% at horizons four, eight and eleven quarters ahead respectively. The differences are all statistically significant, showing that the combination does a much better job than futures at longer time horizons, which are also more policy-relevant. In fact, the only horizons at which the combination does not outperform futures are the first and second quarters ahead. Notably, the four-model forecast combination outperforms not only futures as of the third quarter ahead but also all other models it includes.

In addition, the performance of the four-model combination is very stable over time. For instance, in all sub-samples evaluated, the combination outperforms futures beyond the first and/or second quarter ahead. Moreover, it also outperforms the other three models in most cases, with two notable exceptions: first, the DSGE model when oil prices follow an upward trend and, second, in times of oil price volatility, the risk-adjusted futures model as of the horizon six quarters ahead. The gains offered by the latter are, however, not statistically significant (see Chart 6).



All in all, combining individual projections offers several advantages for oil price forecasting relative to futures. The four-model combination generates a more accurate oil price forecast than futures, especially at longer policy-relevant time horizons, and helps to avoid large forecast errors on average. At the same time, the four-model combination has the disadvantage of being more complex than futures as a forecasting tool.

Overall, the four-model combination is a useful tool for forecasting oil prices. As the combination entails models that contain data on oil fundamentals, it manages to hedge against risks related to strong movements in oil prices which are driven by oil fundamentals, similar to the way in which portfolio diversification hedges against individual investment risk. These strong movements are typically captured less well by futures given their relatively flat profile.

# 6 CONCLUSION

As oil prices have evolved very differently over time, accurately forecasting oil prices using one specific forecasting approach is challenging. Oil price futures, which are used for oil price forecasting by many policy institutions, including the ECB, have the advantage of being a simple and transparent forecasting tool. However, contrary to widespread opinion, futures are only an imperfect reflection of market expectations, and their typically flat and downward sloping profile causes large forecast errors in periods in which oil prices are volatile or steadily increasing. In turn, this can result in large forecast errors for inflation.

Forecast models that include data on economic fundamentals tend to forecast oil prices more accurately than simple benchmarks, although their performance tends to be very unstable over time. As movements in oil prices can to a large extent be explained by changes in oil fundamentals and global economic activity, it has been shown that including information on these variables can improve the oil price forecast in periods when futures do not perform well. A problem with most forecast approaches, however, is that they only manage to capture a specific behaviour of oil prices over particular forecast horizons. As such, their accuracy might be very unstable over time and across forecast horizons.

By pooling individual projections that have different forecast properties, a forecast combination can offer accuracy gains by comparison with an individual forecasting method and at the same time generate a projection which has a more stable performance over time. This article has shown that a four-model combination recently developed at the ECB improves the accuracy of oil price forecasts relative to those based on futures and other individual projections and seems to better hedge against making large forecast errors on average when oil price dynamics change. At the same time, using futures as a baseline has the advantage of providing a transparent and simple tool which is easy to communicate to the public.

It is therefore useful to cross-check the futures-based forecast with the projections based on this four-model combination to assess the risks surrounding the futures-based oil price baseline in the context of the Eurosystem/ECB staff macroeconomic projections exercise.