J.P.Morgan

Global Quantitative & Derivatives Strategy
09 June 2020

Quantitative Perspectives on Cross-Asset Risk Premia

Dissecting Low Vol's exposures, building Balanced Cluster Portfolios with Autoencoders and Latest Model Views

Risk premia performance amid sharp market rebound

Short vol strategies have played well in May as risky assets rebound, but trend-following strategies give back some gains in March as the reversal is too rapid. Quality continues to perform amid market recovery but becomes crowded. A risk parity portfolio delivered a Sharpe ratio above 1.0 in May.

Equity factors get more correlated; Low Vol exhibits short bias to US growth stocks

Even for pure factors that are designed to eliminate exposures to other styles, recent correlations have increased notably. In particular, low vol has moved in tandem with value, and has been underperforming since late 2019. We find that a global low vol portfolio has increased its short bias to volatile growth stocks in the US, and also gained some positive exposures to US value stocks. This explains some of its underperformance as US growth has always dominated value even during March sell-offs.

A novel way to construct balanced cluster portfolio that has better risk-return profiles

Risk premia investors have long been trying to allocate to different styles in a "balanced" manner, but the common solution of risk parity has drawbacks due to selection bias. We investigate the use of principal components and propose a related but more flexible solution based on Autoencoders, which can handle long-only constraints. Backtest results demonstrate superior balance between risk and returns compared with risk parity, especially during the extreme sell-offs in March.

Global Quantitative and Derivatives Strategy

Ada Lau AC
(852) 2800-7618
ada.lau@jpmorgan.com
J.P. Morgan Securities (Asia Pacific) Limited/ J.P. Morgan Broking (Hong Kong) Limited

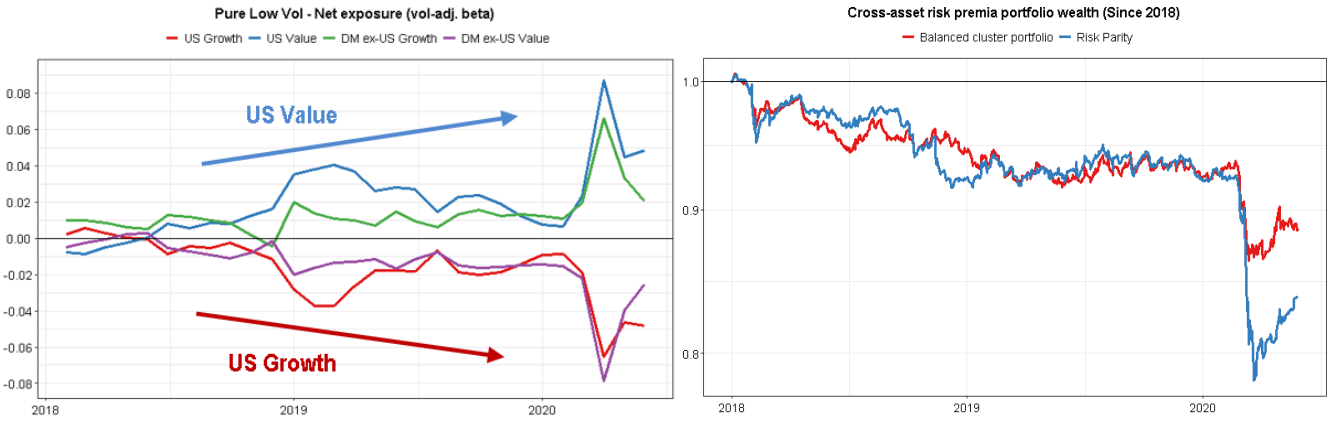
Dobromir Tzotchev, PhD AC
(44-20) 7134-5331
dobromir.tzotchev@jpmorgan.com
J.P. Morgan Securities plc

Rahul Dalmia
(44 20) 7134-5883
rahul.dalmia@jpmorgan.com
J.P. Morgan Securities plc

Marko Kolanovic, PhD
(1-212) 622-3677
marko.kolanovic@jpmorgan.com
J.P. Morgan Securities LLC

Tony SK Lee
(852) 2800-8857
tony.sk.lee@jpmorgan.com
J.P. Morgan Securities (Asia Pacific) Limited/ J.P. Morgan Broking (Hong Kong) Limited

Pure Low Vol exhibits an increasing short bias to US growth (left). Comparing a systematic cluster portfolio with risk parity (right)



Source: J.P. Morgan Quantitative and Derivatives Strategy; Axioma

See page 46 for analyst certification and important disclosures, including non-US analyst disclosures.

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Table of Contents

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

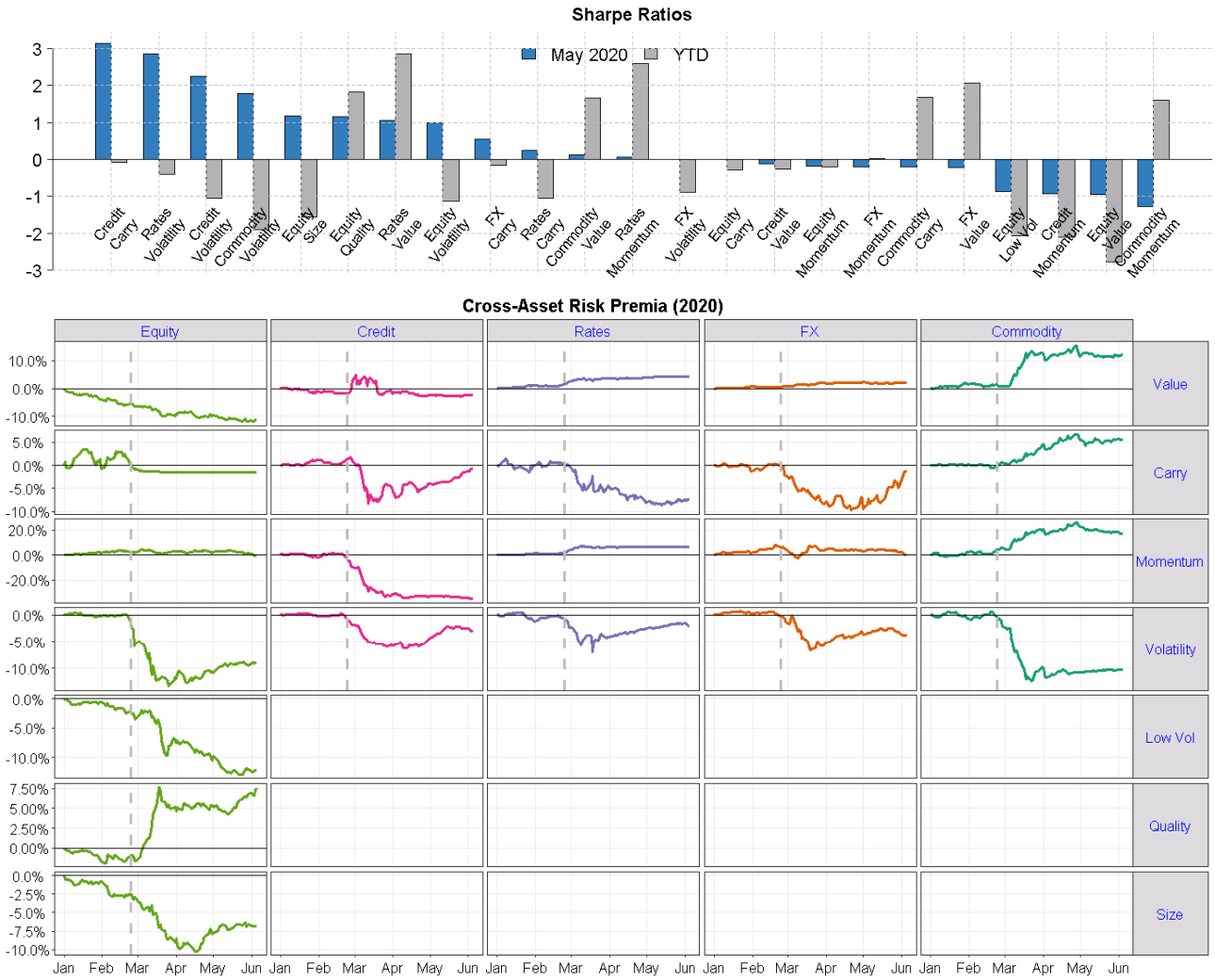
Risk Premia and Market Update

Cross asset risk premia performance

In May we see a sharp rotation back to risky assets after March sell-offs and significant spread tightening amid central banks' easing programs. Credit Carry delivered the best risk-adjusted performance last month as the curve continues to steepen. As we noted in early April, Equity short-vol strategies may start to outperform soon after the massive drawdowns in March. Indeed, the cohort of aggressive short-vol strategies dominated amongst the best performers in May.

Equity Quality is one of the few defensives that continues to play well during the market recovery in May, highlighting that investors still favor stocks with healthy balance sheets and good profitability (although Quality looks crowded). On the other hand, many of the defensive trend-following strategies are caught under this quick V-shaped rebound, especially for those within Commodities.

Figure 1: Recent Sharpe ratios of cross asset risk premia, and cumulative returns since 2020

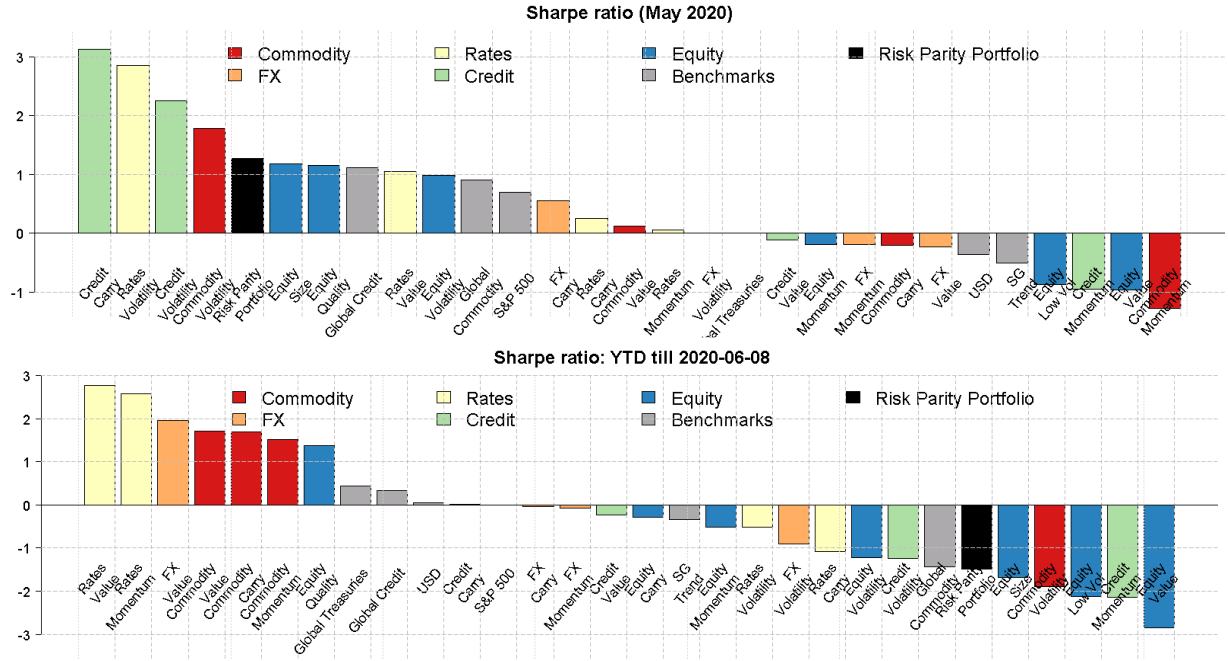


Source: J.P. Morgan Quantitative and Derivatives Strategy

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Figure 2 shows the Sharpe ratios of the cross asset risk premia, comparing with a few asset class benchmarks. It is interesting to note that although Commodity Momentum suffers some loss in May, it still delivers a good Sharpe ratio over 1.5x YTD. Apparently, the risk parity portfolio is biased towards more aggressive risk premia strategies, as it delivers much better Sharpe during the market rebound in May. However, overall performance of the portfolio since 2020 is negative.

Figure 2: Recent Sharpe ratios of risk premia

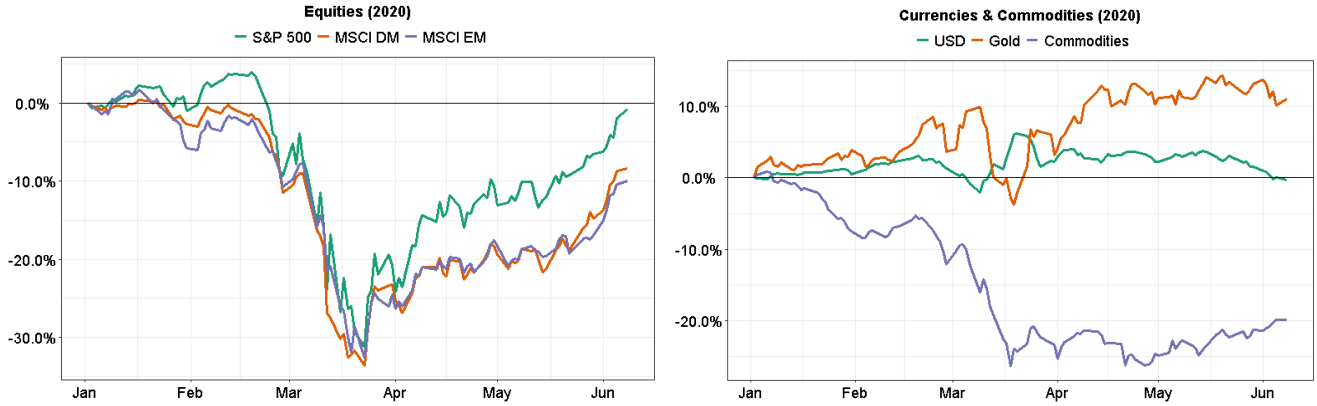


Source: J.P. Morgan Quantitative and Derivatives Strategy

Market and Macro backdrop

While US stocks have been leading the recovery and are ahead of global equities, the recent weakness in the US dollar (Figure 3) maybe a sign of pessimism on how the growth of US economy could be sustainable, with nationwide protests adding on top.

Figure 3: Equities, currencies and commodities performance in 2020

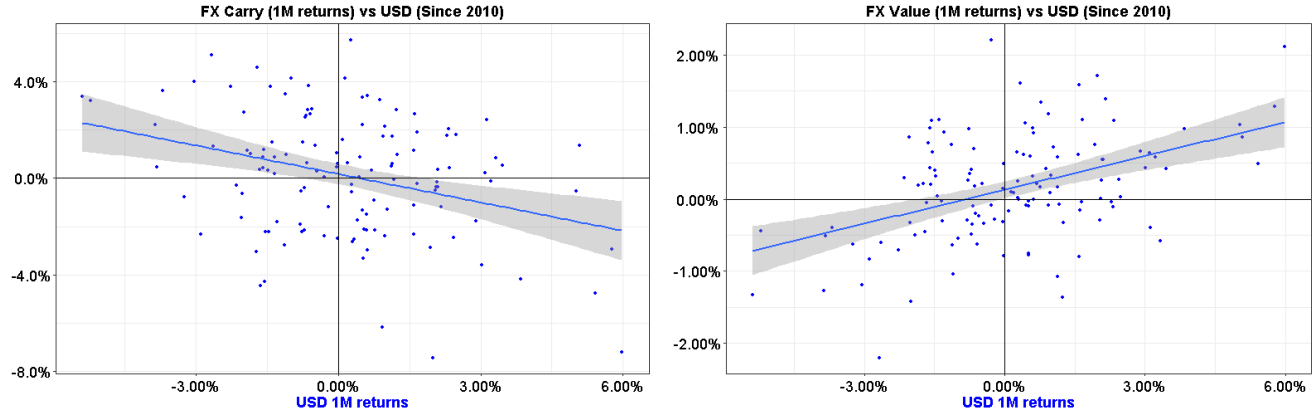


Source: J.P. Morgan Quantitative and Derivatives Strategy

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Our FX strategists just turned to short USD in their model portfolio for the first time since early 2019. Interestingly, analysis on flows and positioning indicated that US corporates have a large short dollar exposure, and CTAs seem to be building up short positions. If USD further weakens, it should benefit the more aggressive FX Carry strategies, as we have discussed in our previous note. We also analyzed the impact of USD strength on FX Value, which has historically been long defensive currencies and tends to be positively correlated with USD strength (Figure 4).

Figure 4: A weakening of US dollar tends to benefit FX Carry but hurts FX Value

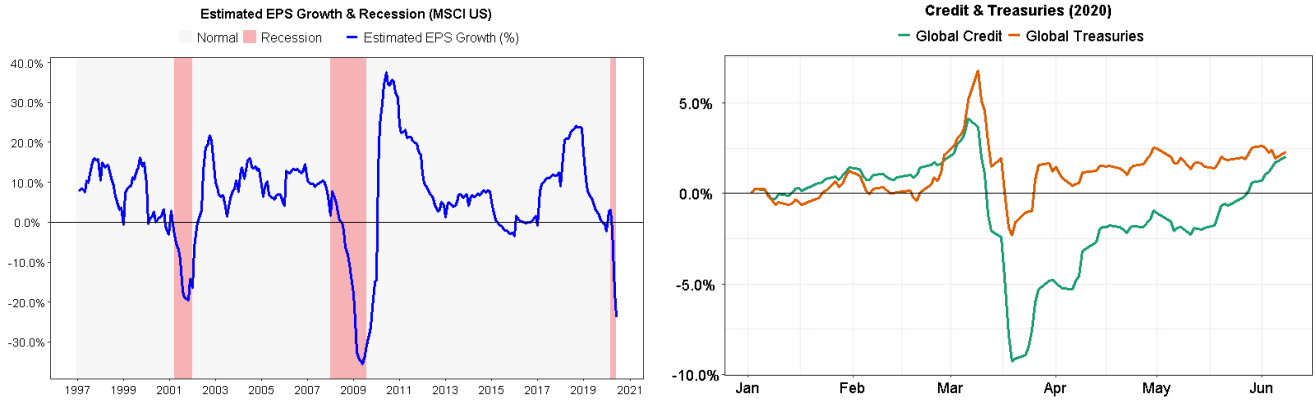


Source: J.P. Morgan Quantitative and Derivatives Strategy

Although there is a huge positive surprise on US non-farm payroll in May (adding 2.5m instead of consensus expectation of losing 7.5m), investors should probably be cautious on the misclassification error as admitted by the Bureau of Labor Statistics (where furloughed employees are labelled as working), which if accounted correctly would imply a further increase in unemployment rate instead of a decrease from 14% in April. We note that forecasted earnings growth in the US is currently around -20%, and may not reach the bottom yet (Figure 5).

Turning to Credit, their recent performance is strong and is now catching up with that of Treasuries since the massive corporate bond-buying programs by central banks to prop up the economy.

Figure 5: EPS growth of US stocks, and performance in credit and treasuries



Source: J.P. Morgan Quantitative and Derivatives Strategy

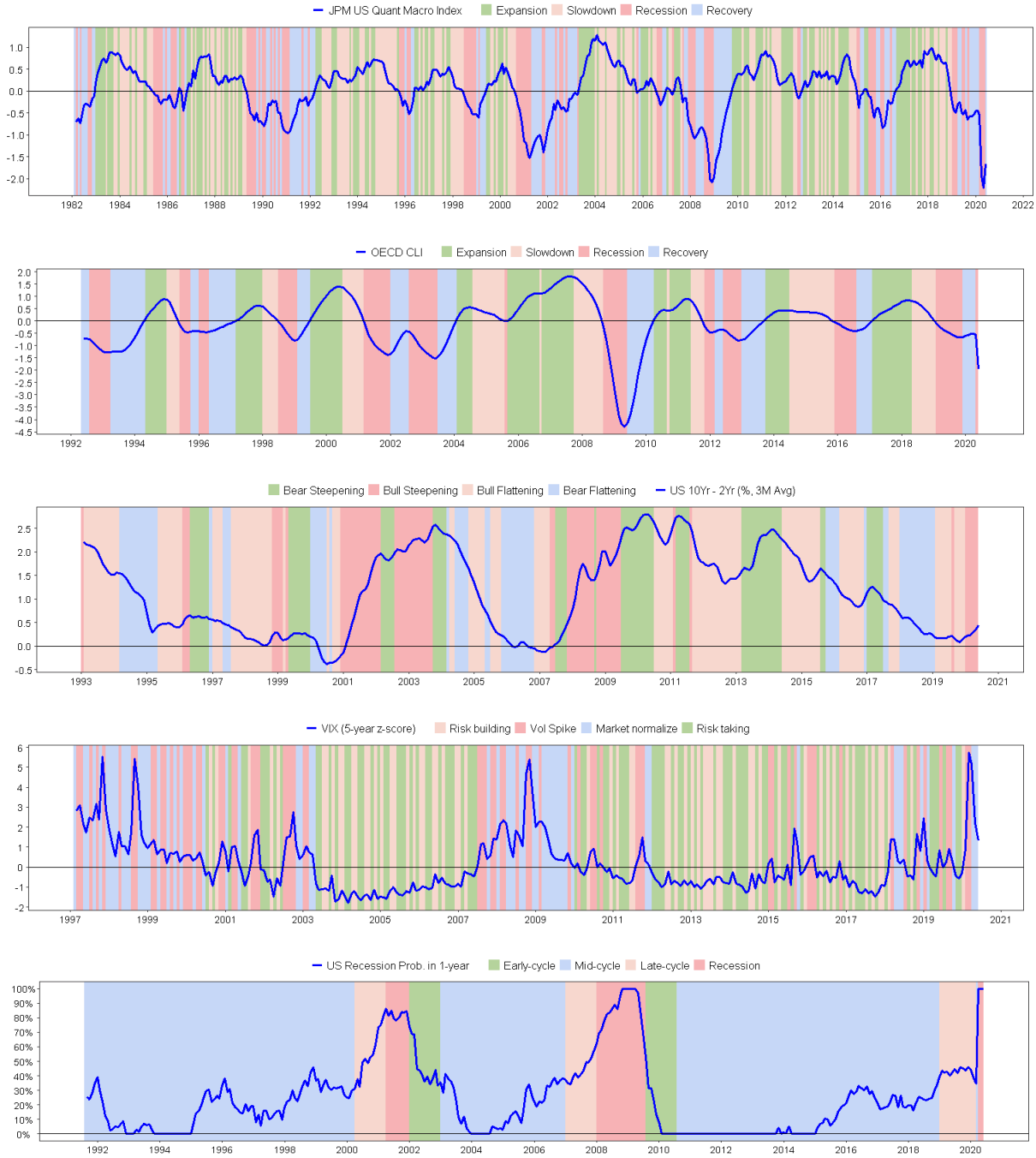
Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Macro Regime Updates

Figure 6 provides an update on the latest macro regimes. As of end of May, the US QMI rebounded from the lows and indicates recovery. The OECD indicator (lagged by 2 months) is in recession, the US yield curve is bull-steepening and volatility normalizes.

Figure 6: Latest macro regimes



Source: J.P. Morgan Quantitative and Derivatives Strategy

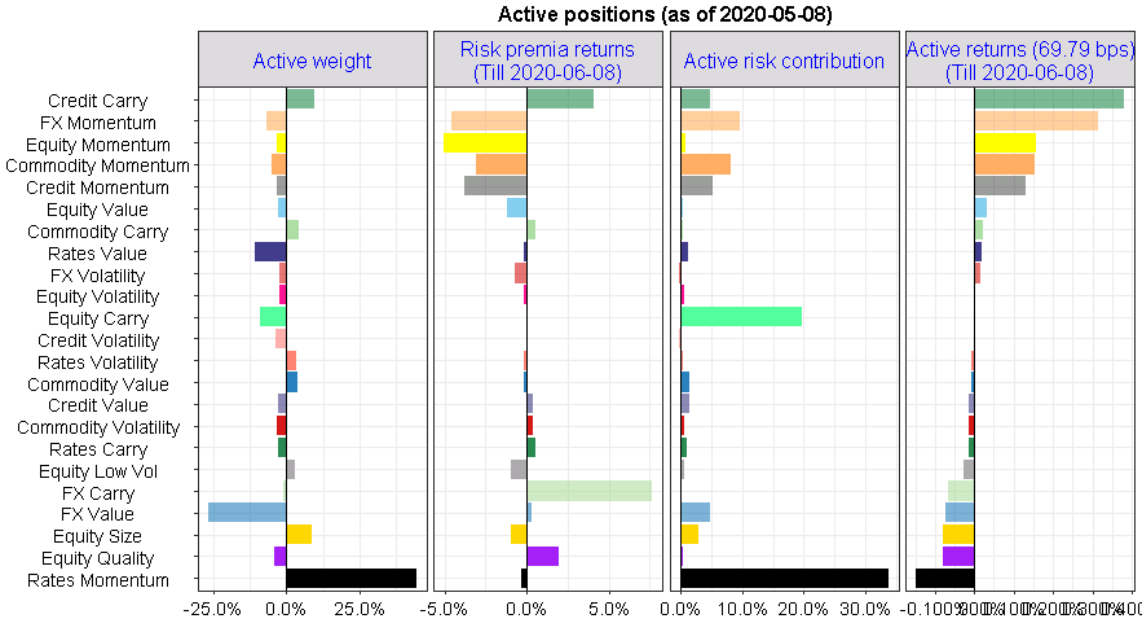
Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Reviewing the Risk Premia portfolio

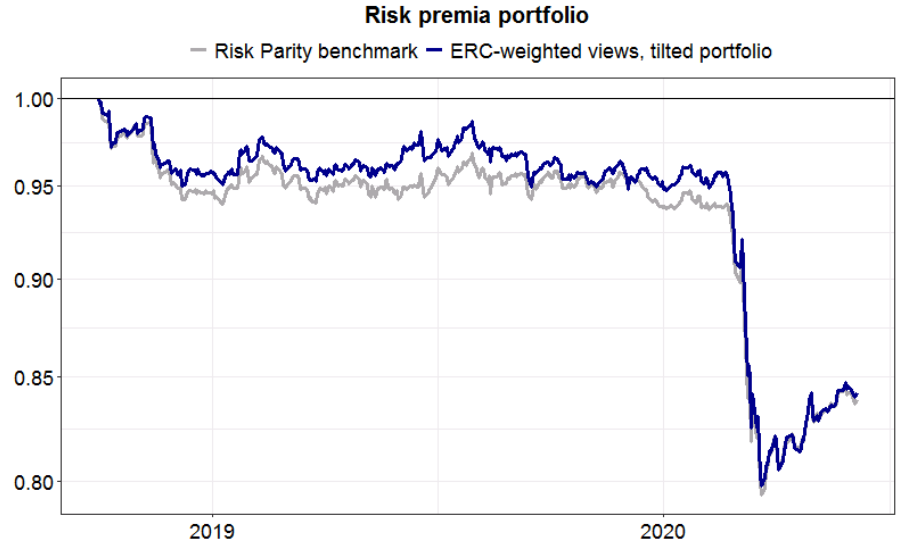
Since we published A Quantitative Framework for Cross-asset Style Timing in October 2018, we keep track of the performance of the tilted portfolio. In Figure 7, we compare the tilted portfolio (based on weighted views from different models) with the risk parity benchmark. Last month we recorded large positive alphas on our OW on Credit Carry, as well as all UW positions on Momentum strategies as they had all delivered negative returns in May amid the V-shaped rebound.

Figure 7: Risk premia active positions last month



Source: J.P. Morgan Quantitative and Derivatives Strategy

Figure 8: Cross asset risk premia portfolio performance



Source: J.P. Morgan Quantitative and Derivatives Strategy

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

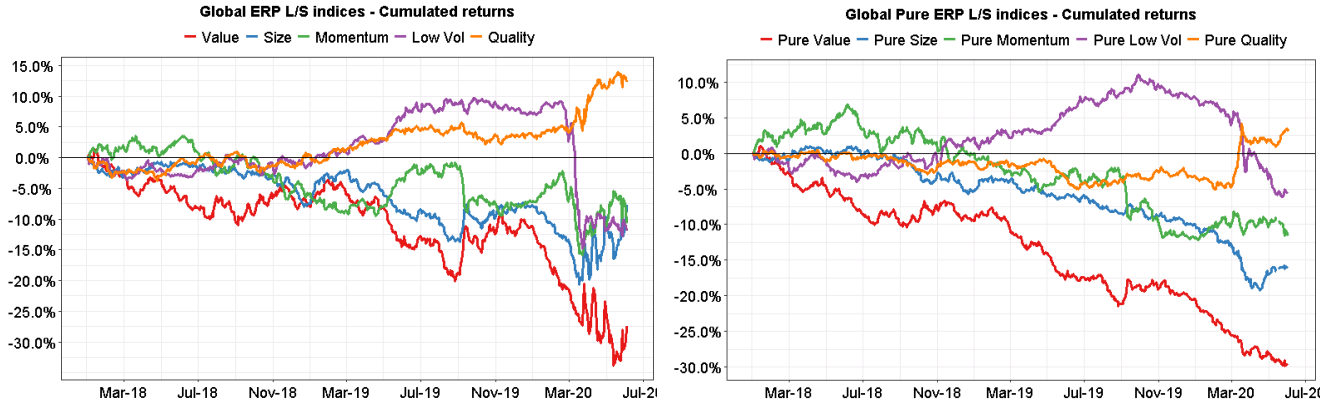
J.P.Morgan

Equity Risk Premia Review

Quality outperforms, but looks crowded

The following provides an update on recent performances of global equity risk premia. The equities sell-off in March has highlighted the defensiveness in Quality, which is the only equity risk premia (whether in raw or pure version) with positive performance YTD. Momentum is flattish during the sell-off, while Value, Low vol and Size have been down (Figure 9).

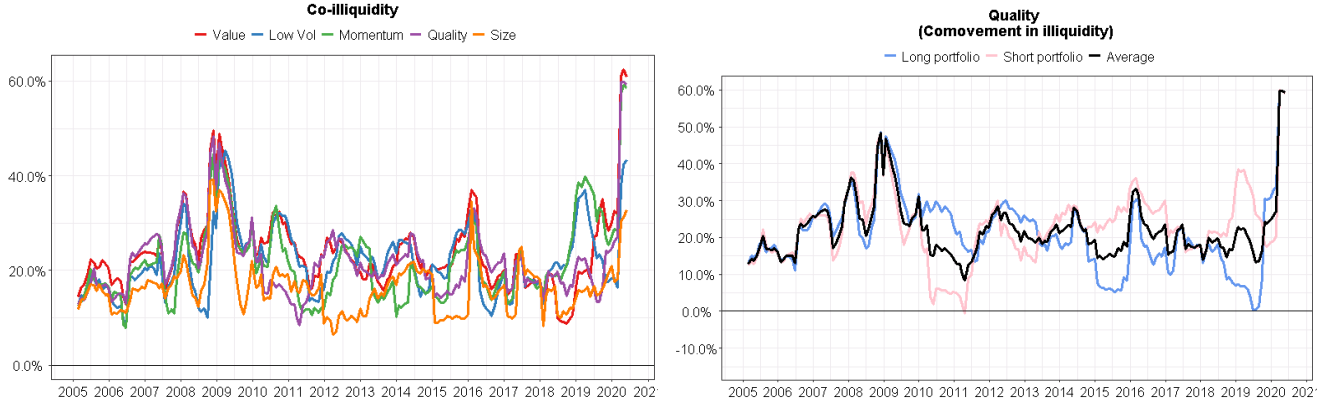
Figure 9: Raw ERP (left) and Pure ERP (right) cumulative returns since 2018



Source: J.P. Morgan Quantitative and Derivatives Strategy

Quality, Value and Momentum are most crowded under the measure of co-illiquidity, i.e. the co-movements of illiquidity shocks amongst stocks in the factor portfolios. It is interesting to note that good quality stocks are not crowded at all back in mid-2019, but since 2020 they have exhibited a significant surge in crowdedness as investor's flight to safety. High crowdedness in Quality and Momentum in general lead to poor future returns. The recent outperformance in Quality may be difficult to sustain too long, and we note that Momentum has underperformed since it started to look crowded in late 2018.

Figure 10: Crowdedness measure of equity factors based on co-illiquidity (higher = more crowded)



Source: J.P. Morgan Quantitative and Derivatives Strategy

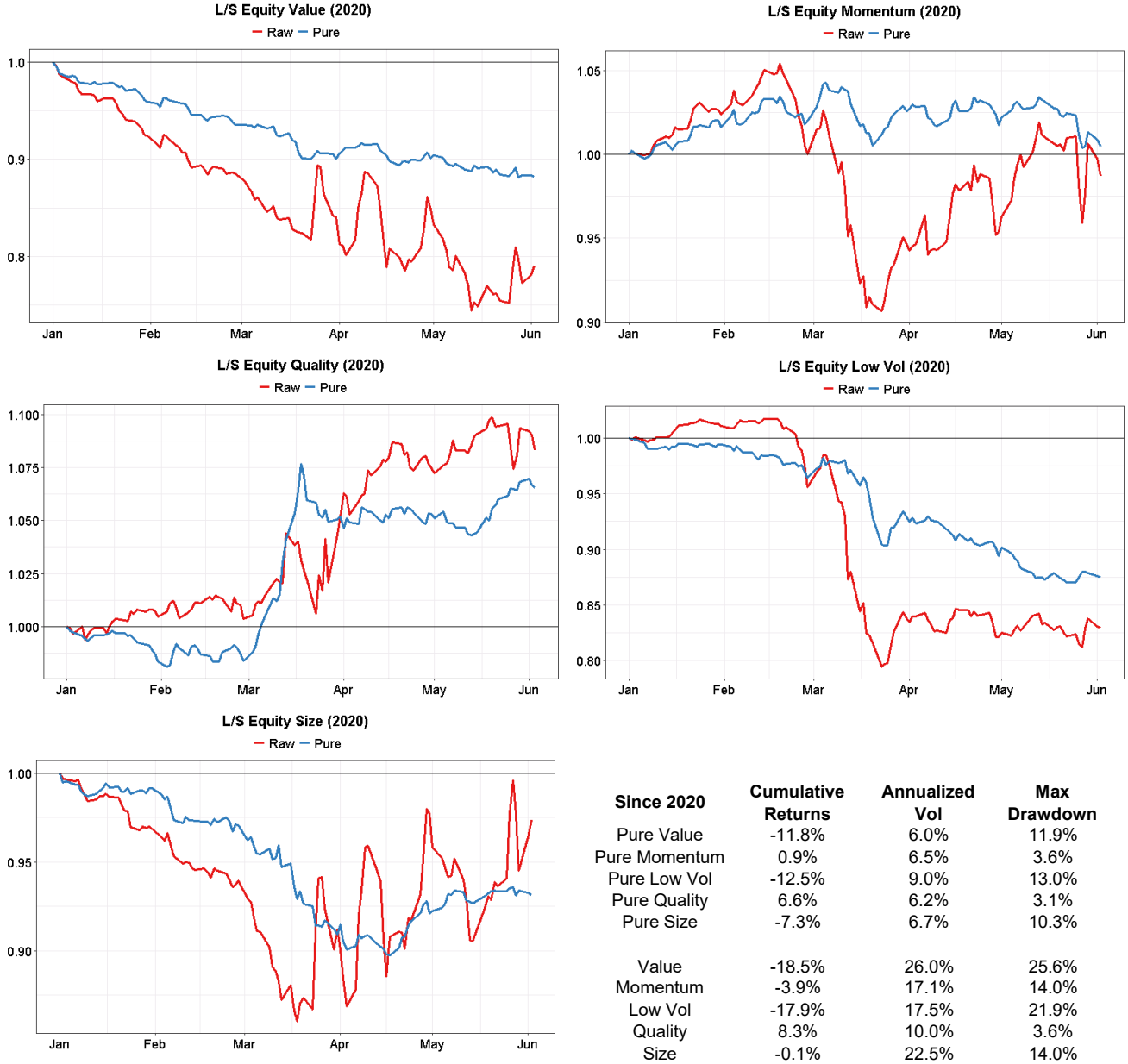
Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Pure factors are less volatile

Recent performances of pure vs raw equity factors are pretty much in line, with Value and Low Vol trending downwards, Quality outperforming and Size exhibiting rebounds since market bottoms in late March. Nevertheless, we observe much more volatile returns in raw equity factors, which highlights the benefits of better control of risk exposures amongst pure factors.

Figure 11: Pure vs Raw risk premia (2020)



Since 2020	Cumulative Returns	Annualized Vol	Max Drawdown
Pure Value	-11.8%	6.0%	11.9%
Pure Momentum	0.9%	6.5%	3.6%
Pure Low Vol	-12.5%	9.0%	13.0%
Pure Quality	6.6%	6.2%	3.1%
Pure Size	-7.3%	6.7%	10.3%
Value	-18.5%	26.0%	25.6%
Momentum	-3.9%	17.1%	14.0%
Low Vol	-17.9%	17.5%	21.9%
Quality	8.3%	10.0%	3.6%
Size	-0.1%	22.5%	14.0%

Source: J.P. Morgan Quantitative and Derivatives Strategy

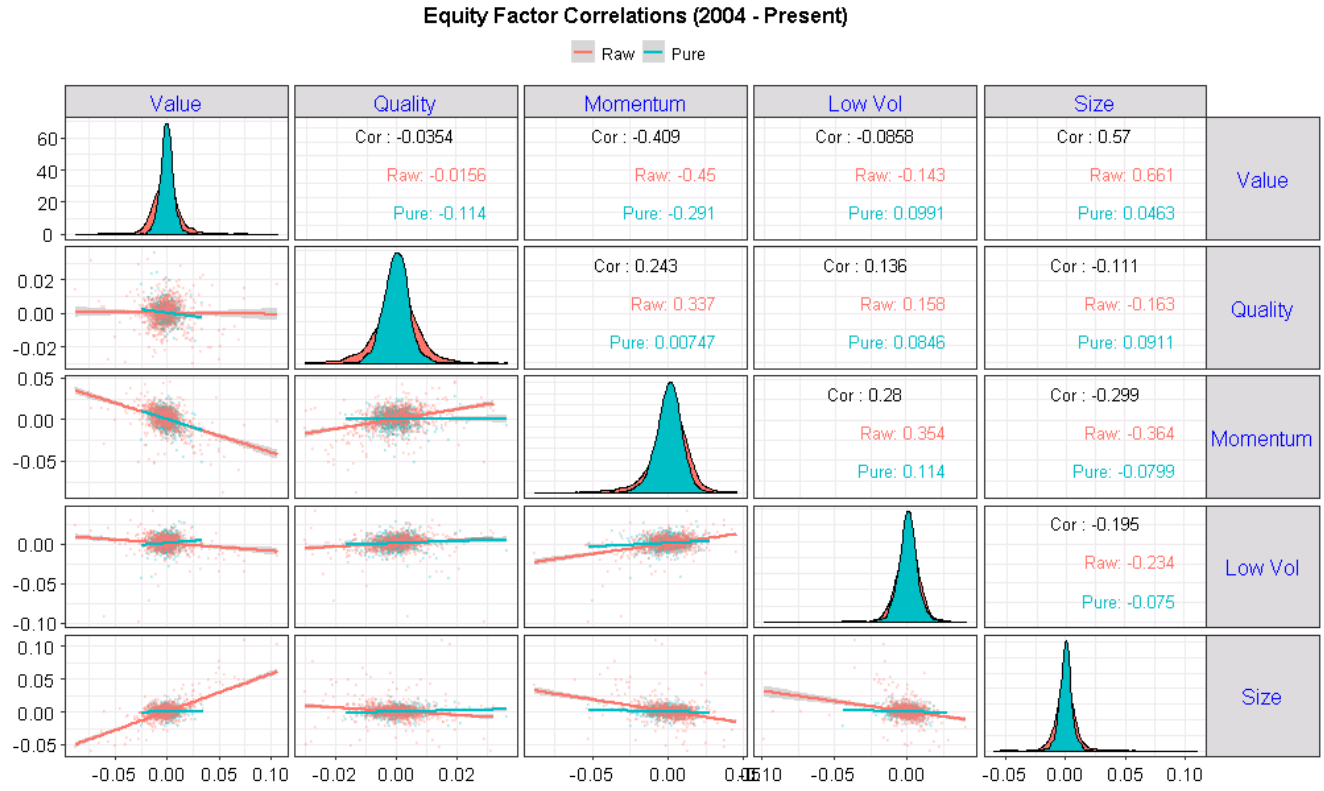
Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Factor correlations have increased

Here we examine the correlations amongst equity factors, comparing correlations between raw factors (which could be high) as well as those between pure factors (which should be low as we control exposures in the design). In Figure 12, we see that pure factors do exhibit low correlations, although value and momentum is slightly negatively correlated (-0.29, still lower than -0.45 in raw factors). Pure Value is uncorrelated with Pure Size, whereas in the raw versions, Value and Size are very similar factors as both have strong bias in small caps. This re-iterates the fact that pure factors are better building blocks for risk premia portfolios.

Figure 12: Equity factor long-term correlations based on weekly returns since 2004. Charts on lower triangles show the scatter plots of weekly returns together with a linear fit. Charts on the diagonal show the distribution of returns. (Note: correlations in black is based on all data regardless of raw or pure).



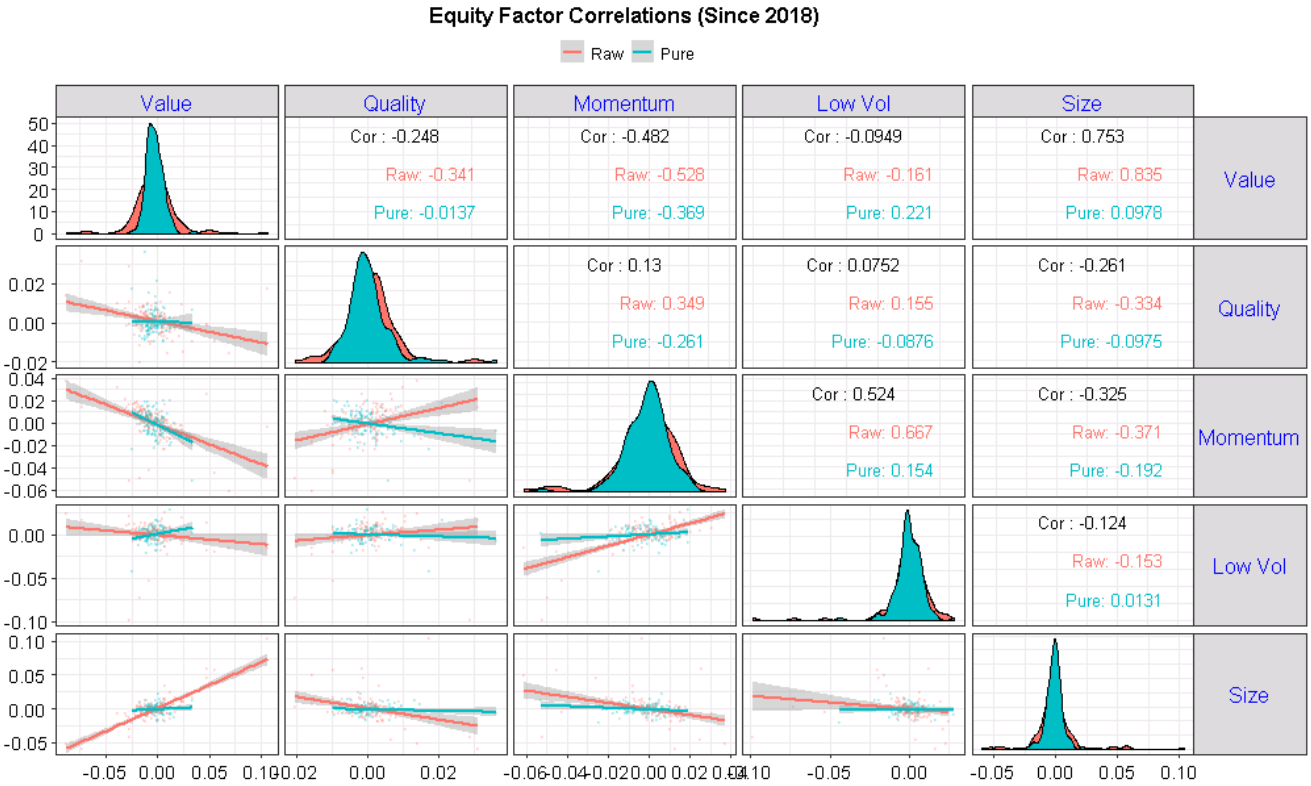
Source: J.P. Morgan Quantitative and Derivatives Strategy

Next we look at recent correlations using weekly returns since 2018. Since then, we find that correlations between some of the Pure ERPs have increased (Figure 13):

- Pure Value and Pure Momentum become more negatively correlated (-0.37)
- Pure Quality and Pure Momentum become more negatively correlated (-0.26)
- Pure Value and Pure Low Vol become more positively correlated (0.22)

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Figure 13: Equity factor correlations based on weekly returns since 2018. Charts on lower triangles show the scatter plots of weekly returns together with a linear fit. Charts on the diagonal show the distribution of returns. (Note: correlations in black is based on all data regardless of raw or pure).



Source: J.P. Morgan Quantitative and Derivatives Strategy

Intuitively, we expect Low Vol and Value to be quite different factors, especially from a yield perspective. In general, Low Vol enjoys a low yield environment whilst Value prefers an increase in rates (which partly proxy economic growth).

However, from the above correlation plots, it is a bit peculiar to see that Pure Low Vol is starting to move in tandem with Pure Value. Since Sep 2019, both Pure Value and Pure Low Vol have been trending downwards. We also notice that Low Vol does not provide the expected defensive hedge during the recent March sell-off. Regarding this question, we attempt to shed some light on the exposure of Low Vol in the next section.

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

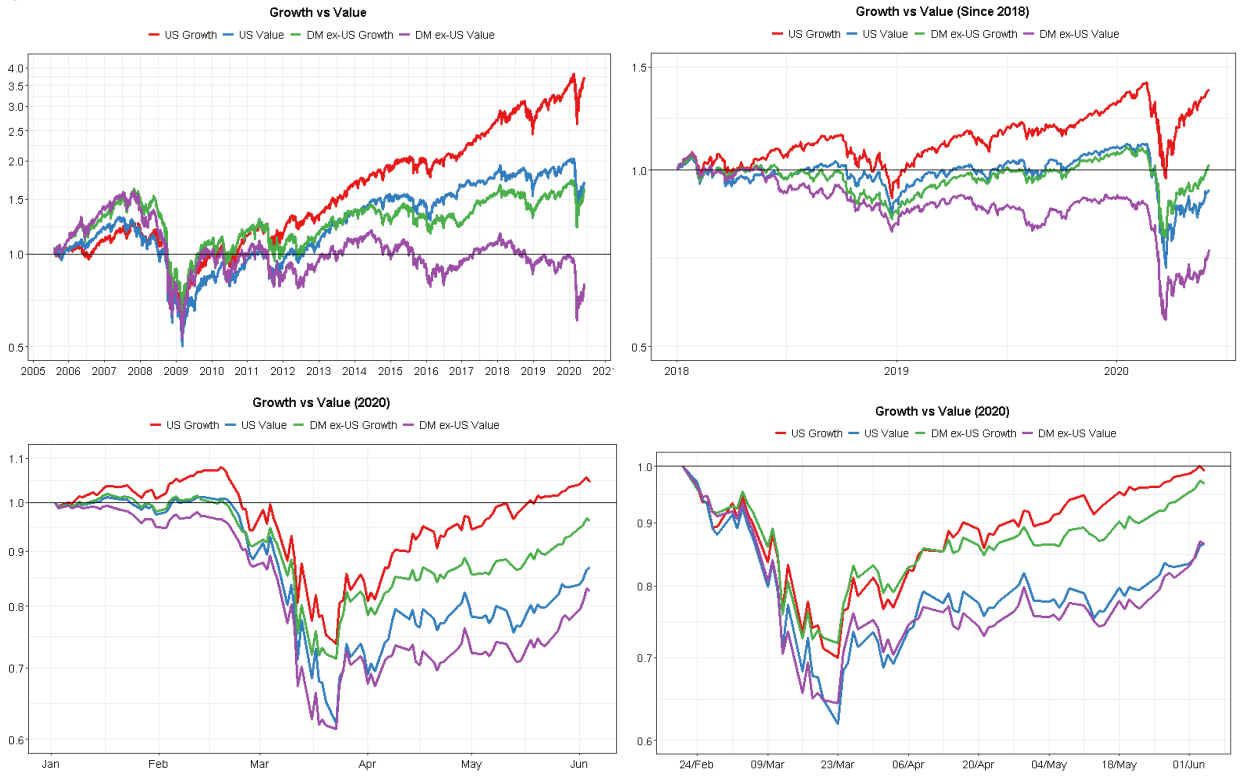
Pure Low Vol exhibits short bias on US Growth

One possibility of Low Vol performing more similar to Value recently maybe due to the exposure to volatile growth stocks (e.g. technology). While traditional Value must be shorting those stocks, is it true that Low Vol portfolios are also exhibiting some sort of short bias on growth? We may run a relatively "naïve" decomposition on the portfolio using only two factors: Value vs Growth. The intuition is that value and growth stocks are largely non-overlapping, and they are kind of the opposite to each other. We can do this using our custom portfolio decomposition framework, which runs regressions on portfolio holdings rather than portfolio returns. An advantage is that the sensitivities on the factors (i.e. betas) would be much more timely using the holdings-based regressions, because we do not need to consider lookback windows. As the universe of the pure factors include stocks in global developed markets, we decompose the pure factors using portfolio holdings in 4 Value or Growth ETFs:

- US Growth (IWF US Equity)
- US Value (IWD US Equity)
- DM ex-US Growth (EFG US Equity)
- DM ex-US Value (EFV US Equity)

The performance of the above Value and Growth ETFs are shown in Figure 14. Clearly, Growth has been outperforming Value for over 10 years since the GFC, and US equities have been faring much better than their global counterparts in all timeframes, including the recent sell-offs and subsequent rebound.

Figure 14: Value and Growth performance since 2005, 2018, 2020 and the sell-off in March

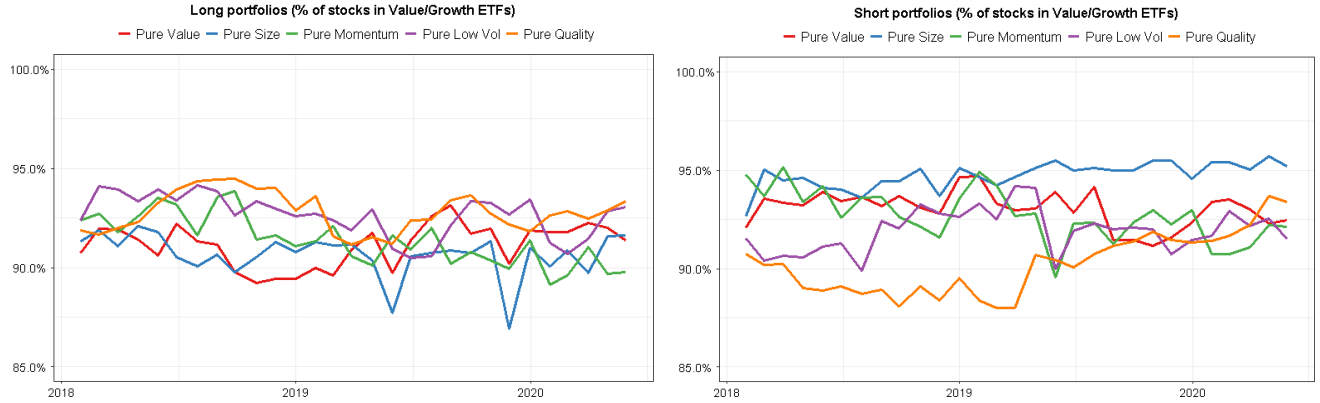


Source: J.P. Morgan Quantitative and Derivatives Strategy

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

We may wonder whether decomposing the portfolios using the above 4 ETFs is appropriate. If we look at the overlapping positions in the ETFs, we find that indeed they are relatively "orthogonal" in terms of stock positions, i.e. they are holding largely different stocks. Overlapping stock positions between US Growth and Value is about 30%, and that between DM ex-US Growth and Value is about 10%. We also check if the stocks in the Pure ERP portfolios fall into at least one of the ETFs. Figure 15 shows that about 90-95% of stocks are indeed present in the ETF portfolios, hence the ETF portfolios could "span" the Pure portfolio.

Figure 15: Percentage of stocks in Pure ERP portfolios that are present in the Value or Growth ETFs



Source: J.P. Morgan Quantitative and Derivatives Strategy

We then run a holdings-based regression for the Pure factor portfolio at every month-end:

$$\boldsymbol{h}_p = \boldsymbol{H}_f\,\boldsymbol{\beta} + \boldsymbol{\epsilon}$$

$$holdings = H_{US\ Gr}\beta_{US\ Gr} + H_{US\ Val}\beta_{US\ Val} + H_{DM\ Gr}\beta_{DM\ Gr} + H_{DM\ Val}\beta_{DM\ Val} + \epsilon$$

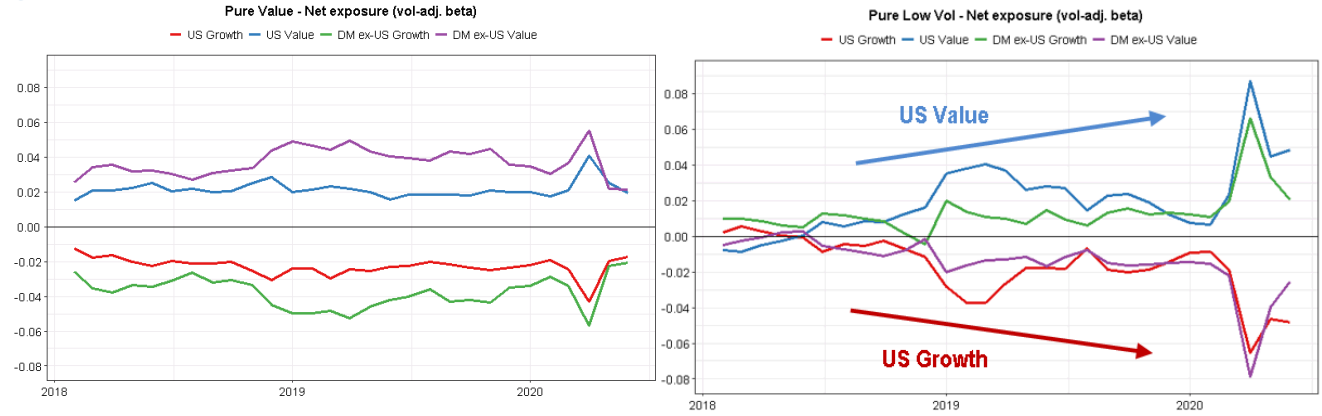
where *H* are the column vectors of holdings in the ETFs, and the betas correspond to the exposure. Since a small beta on a volatile factor could matter more than a large beta on a stable factor, we further multiply the beta with the factor volatility to obtain the vol-adjusted beta for fairer comparison.

Figure 16 compares the exposure of Pure Value and Pure Low Vol respectively. One may regard this exercise on Pure Value as a demonstration of the framework, which confirms the positive exposures to Value and negative exposures to Growth, as expected. A side result is that we can further analyze the exposure difference between US and non-US equities. For instance, exposure to non-US equities have decreased recently in the Value portfolio.

Interestingly, we find that Pure Low Vol has become more positively exposed to US Value and more negatively exposed to US Growth since 2018 (Figure 16). Net exposures in 2018 have been much smaller than recent exposures. The increasingly negative exposure on US Growth has likely hurt the performance of Pure Low Vol recently, including the March sell-off as Growth has continued to outperform during that period (Figure 14).

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Figure 16: Net exposure to Value and Growth ETFs in Pure Low Vol and Pure Value



Source: J.P. Morgan Quantitative and Derivatives Strategy, Axioma

To confirm the above results, we run a snapshot of risk exposure analysis using Axioma's global risk model, which decompose portfolio exposures into market, style, country, industry and currency factors. This analysis reveals that:

- Pure Low Vol has major risk contribution due to style exposures and not country or sector. However, risk contributions from sectors may still be sizable as sector factors tend to be more volatile
- Amongst style factors, the main contributions are from the bias towards low vol and low beta, as intended
- As of 2020 May, pure low vol is shorting Momentum and Growth, shorting Software, Semiconductors and Internet retail, and buying REITs

Overall, results from Axioma supports the net short positions of Growth in Pure Low Vol. In addition, risk contribution from Growth was much lower back in 2018.

Figure 17: Risk exposure analysis of Pure Low Vol portfolio based on Axioma global risk model

2018 Jan			2020 May		
Total	**Exposure**	**Risk Contribution (%)**	**Total**	**Exposure**	**Risk Contribution (%)**
Style	-1.32	89.7	Style	-1.42	86.9
Country	0.23	-1.7	Country	0.09	1.3
Industry	0.23	19.5	Industry	0.09	19.1
Currency	0.09	3.1	Currency	0.03	2.4
Style			**Style**		
Volatility	-0.81	65.5	Volatility	-0.55	51.8
Market Sensitivity	-0.37	20.1	Market Sensitivity	-0.29	32.1
Size	0.09	3.2	Medium-Term Momentum	-0.09	-2.7
Value	-0.12	2.0	Growth	-0.30	2.1
Dividend Yield	0.18	-1.0	Value	-0.12	1.8
Liquidity	-0.15	1.0	Earnings Yield	0.07	0.8
Medium-Term Momentum	-0.04	-0.8	Liquidity	-0.06	0.7
Growth	-0.17	-0.3	Exchange Rate Sensitivity	-0.24	0.5
Leverage	0.19	-0.3	Leverage	0.05	0.4
Earnings Yield	0.06	0.3	Size	0.02	-0.4
Exchange Rate Sensitivity	-0.24	-0.2	Profitability	0.10	-0.2
Profitability	0.06	0.2	Dividend Yield	-0.01	0.0
Industry			**Industry**		
Biotechnology	-0.05	6.4	Software	-0.04	4.2
Metals & Mining	-0.03	3.2	REITs	0.01	3.9
IT Services	0.04	2.6	Semiconductors	-0.03	2.9
Health Care Equipment & Supplies	0.04	2.1	Internet & Direct Marketing Retail	-0.02	2.5
Banks	-0.04	1.7	IT Services	0.07	2.3

Source: J.P. Morgan Quantitative and Derivatives Strategy, Axioma

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Balanced Cluster Portfolio based on underlying features

One of the many questions faced by alternative risk premia investors is on how to choose a "proper" universe of risk premia to begin with. After all, there is a plethora of risk premia indices on the market, and simply judging from historical performance will likely sacrifice diversification benefits of some risk premia. In the case where an investor does not have many constraints, we do find that a simple risk parity portfolio with a large number of risk premia indices tends to deliver the highest Sharpe ratio, which in general outperforms a more concentrated portfolio with fewer indices. Nevertheless, this selection of a "large number of risk premia" can still be rather heuristic, and we see that such portfolios could experience large drawdowns we well, highlighting that the diversification benefit maybe overstated when it is most needed.

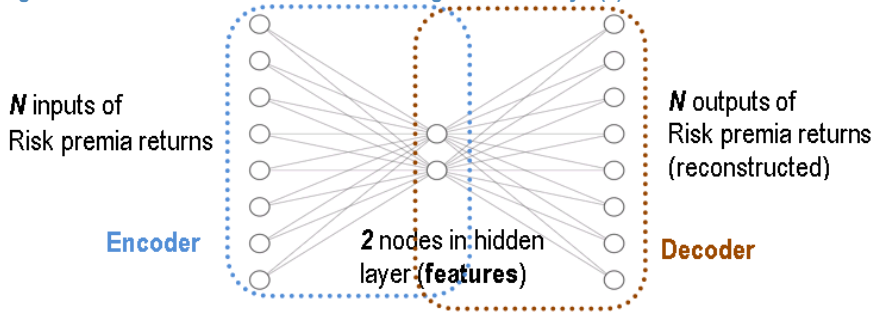
Systematically identify lowly correlated clusters

Below, we look into a new, systematic way to classify a universe of risk premia into two lowly correlated clusters. The rationale is simple: Intuitively there are two groups of risk premia, i.e. Aggressive vs Defensive (which we have looked at heuristically in our note in April). **We expect Aggressive and Defensive risk premia to be largely uncorrelated (or even negatively correlated) at all times**, unlike some of the individual risk premia which may become more correlated across certain market regimes. As such, it could be beneficial if we put the same risk budget on the two clusters rather than the same risk budget to each risk premia. The question boils down to identifying the correct clusters out-of-sample.

Constrained Principal Components via Autoencoders

The first solution comes into mind is to look for the first two Principal Components (PCs), which are linearly combinations of risk premia that represent the most information (i.e. variance in the data). However, some weights would likely be negative, meaning that we short some risk premia which is typically not preferred. One can ensure positive weights using constrained optimization[1]. Here we look at another approach using autoencoders, which is a special type of neural network that maps the inputs into itself.

Figure 18: Autoencoders extract features using the hidden layer(s).



Source: J.P. Morgan Quantitative and Derivatives Strategy

[1] For instance, non-negative matrix factorization is a popular tool to decompose facial images into sparse, meaning features (e.g. eyes, nose, mouth)

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

An autoencoder achieves dimension reduction via the "bottleneck", i.e. the hidden layer with a small number of nodes compared with the input layer. The reason we look at autoencoders is because it is a useful and flexible tool: Principal Components are simply a special case when we consider one hidden layer with linear activations and minimize the mean squared errors. Autoencoders are flexible as:

- One could consider non-linear features using more hidden layers and non-linear activation functions (e.g. sigmoid), which can be useful in other applications such as feature engineering
- Constraints could be imposed on the weights (and also on activations) using existing tools in Keras and Tensorflow
- One could regularize the optimization to prevent overfitting, which could improve out-of-sample performance (i.e. we ensure the features are genuine)

Note that the features extracted by Autoencoders may not always be uncorrelated as in the case of Principal Components. However, we can put it as a constraint to ensure uncorrelated features. This will not be able to achieve easily if we construct clusters based on hierarchical clustering (Figure 19).

Figure 19: Comparison between different methods to construct cluster portfolios

	Principal Components	Hierarchical Clustering	Autoencoders
Long-only	No	Yes	Yes (via constraints)
Output asset weights	Yes	No	Yes
Uncorrelated features	Yes (by construction)	No	Yes (via constraints)
Cross-validation	No	No	Yes

Source: J.P. Morgan Quantitative and Derivatives Strategy

Example on risk premia portfolio

In the below, we estimate the weights in the autoencoder at the beginning of each year, using the 23 risk premia returns as inputs (see Appendix). To ensure the features are not simply dominated by the more volatile risk premia, we scale the returns to target at same volatility. We impose the following constraints:

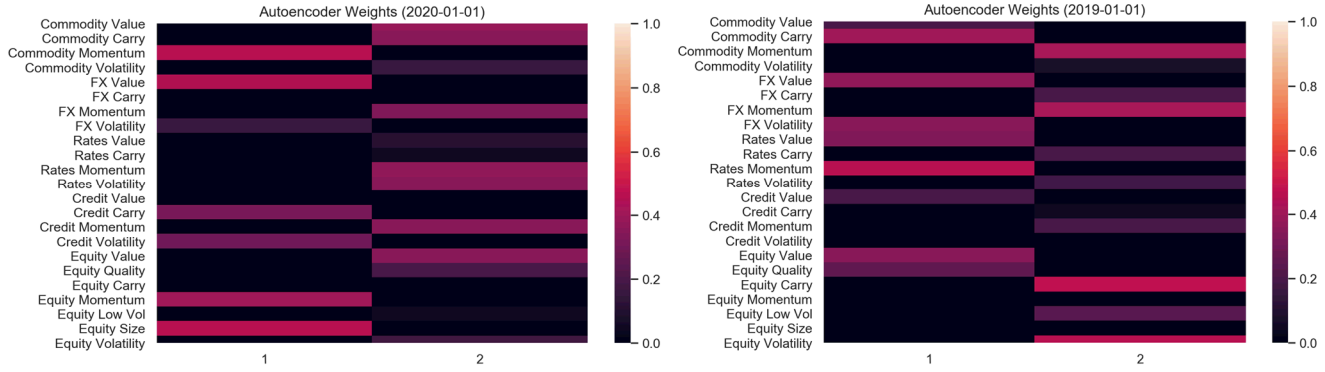
- Encoder weights are the same as decoder weights (so as to reduce the number of parameters, and to make it resembles principal components)
- All weights are positive and the column vectors have unit norm
- Encoder weights are orthogonal (so a risk premia only falls into one of the clusters)
- Features are uncorrelated

We run through a parameter grid search and finalize a model each year, using an expanding window and the most recent 20% of data as the test set for validation. We also include weight regularizations, which leads to a relatively sparse representation and some risk premia may not fall into any clusters.

Each year, we extract the estimated weights of the encoder and use it to construct a long-only portfolio of risk premia, keeping the same composition in the next 12 months. Encoder weights in recent years are shown in Figure 20.

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

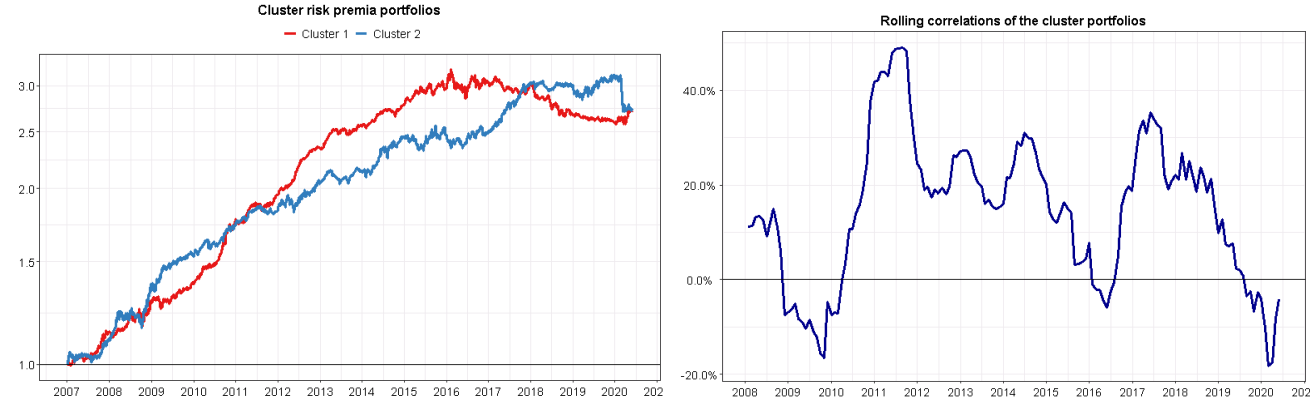
Figure 20: Encoder weights on each risk premia for the 2 clusters



Source: J.P. Morgan Quantitative and Derivatives Strategy

In the model estimated in the beginning of 2020, cluster 2 tilts towards aggressive (Rates Volatility) while cluster 1 is more defensive (e.g. FX Value, Commodity Momentum), as shown in the performance in Figure 21. It is important to note that these cluster returns are out-of-sample: we estimate and fix the cluster weights at the beginning of each year. As we constrain the features to be uncorrelated, the solutions do exhibit relatively low level of correlations, except in 2011 when apparently most risk premia returns were positive.

Figure 21: Performance of the cluster portfolios (re-estimated every year), and rolling correlations between the cluster portfolio returns



Source: J.P. Morgan Quantitative and Derivatives Strategy

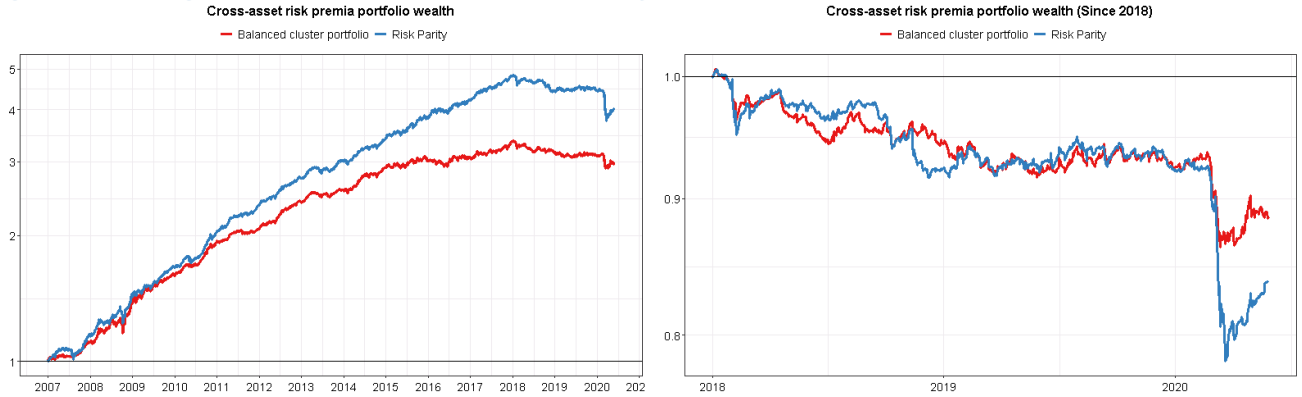
Finally, we assign a risk parity weight on the 2 cluster portfolios based on their historical volatilities, and target the overall portfolio to 5% vol. In summary, we compare two portfolios:

- **Balanced cluster portfolio** (risk parity with 2 sparse, uncorrelated clusters)
- **Risk Parity portfolio** (risk parity with 23 individual risk premia)

Figure 22 compares the two approaches. The balanced cluster portfolio appears to have much better control on skewness, kurtosis and drawdowns, although this also leads to some sacrifice of high returns during the good days. During the recent sell-offs in March, the balanced cluster portfolio demonstrated much better resilience than the naïve risk parity benchmark.

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Figure 22: Comparing the balanced cluster portfolio and the risk parity portfolio



	Start Date	End Date	Annualized Returns	Annualized Vol	Sharpe Ratio	t-stat	Skewness	Excess Kurtosis	Max Drawdown	Hit Ratio	Sortino Ratio	Calmer Ratio
Balanced cluster portfolio	2007-01-02	2020-05-27	8.2%	5.3%	1.55	5.65	-0.31	4.10	14.3%	56.4%	0.14	0.57
Risk Parity	2007-01-02	2020-05-27	10.6%	5.6%	1.88	6.75	-1.48	15.53	22.3%	58.7%	0.16	0.47

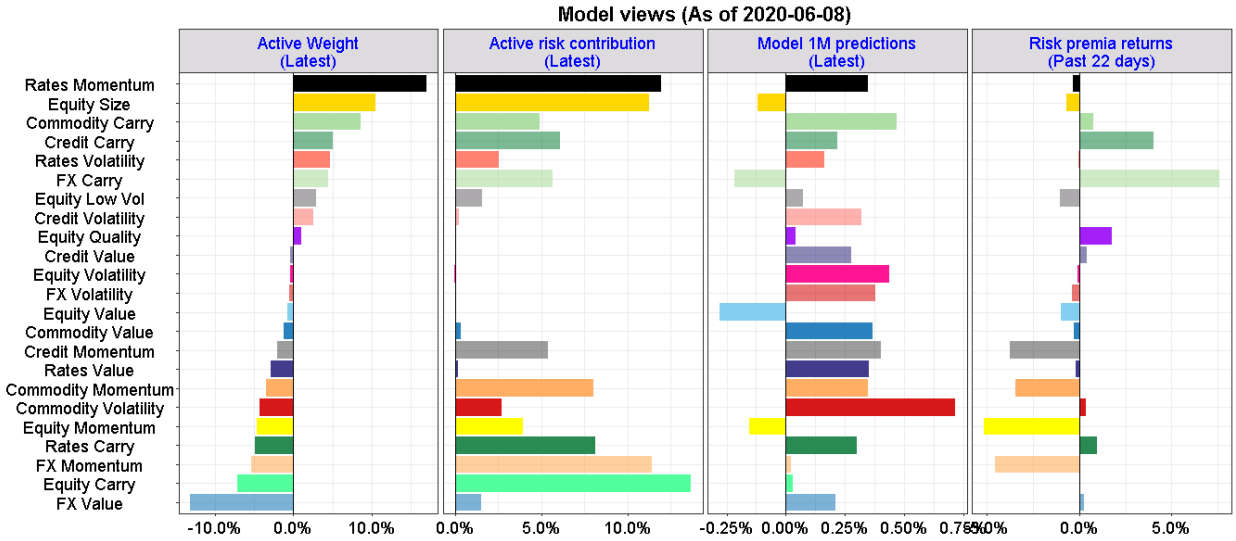
Source: J.P. Morgan Quantitative and Derivatives Strategy

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Latest Model Views

In "A Quantitative Framework for Cross-Asset Style Timing", we introduced an approach to construct views from a large set of models (macro-regime, time-series, Machine Learning), and implement such views to tilt a cross-asset risk premia portfolio relative to the risk parity benchmark. Figure 23 shows the latest active weights, active risks and model predictions.

Figure 23: Latest active positions relative to risk parity



Source: J.P. Morgan Quantitative and Derivatives Strategy

Figure 24 shows the details of the model predictions (i.e. aggregated forecasts and the weighted average from each of the 5 groups of models).

Figure 24: Model portfolio and some more details on model forecasts

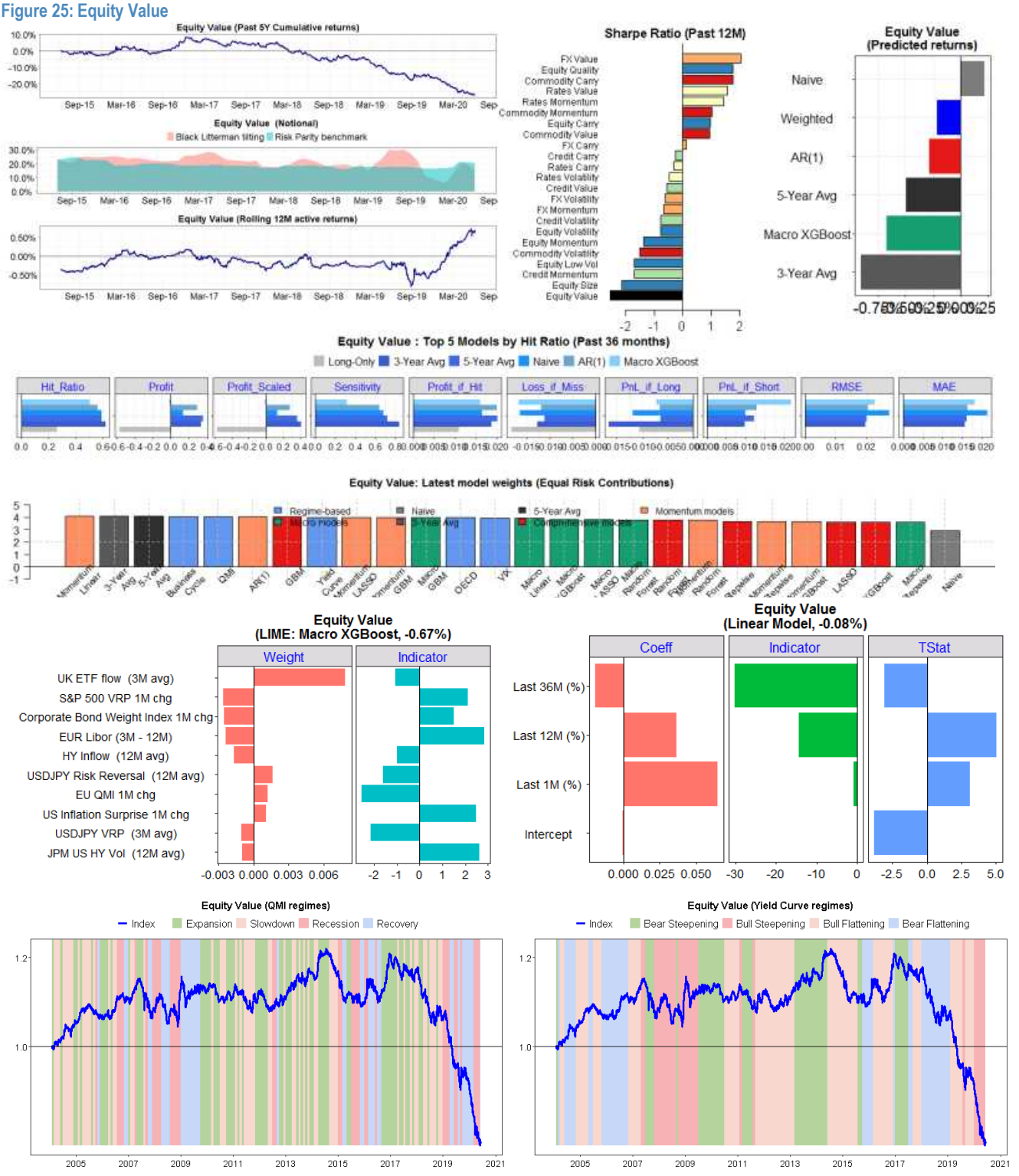
	Aggregated Forecast (bps)	Aggregated Forecast / Volatility	Model Forecasted Returns (bps, weighted) (Sum to Aggregated Forecast)					Notional (x 100) (5% Vol Target)				Risk (%)		
			Benchmark	Economic Regime	Macro & Financial Forecasting	Time Series	Comprehensive	Risk Parity	Tilted Portfolio	Active Tilting	Active Tilting / Volatility	Vol	Portfolio Risk Contribution	Active Risk Contribution
Equity Value	-28.0	-0.17	-5.1	-3.8	-2.5	-16.4	-0.2	20.5	19.8	-0.7	-0.1	5.8	3.9	0.1
Equity Quality	4.3	0.03	1.7	1.6	-1.2	2.1	0.1	25.0	26.0	1.0	0.2	4.8	4.6	0.1
Equity Carry	3.1	0.01	1.0	11.6	-9.1	9.9	-10.3	14.4	7.2	-7.2	-0.9	8.2	1.1	13.7
Equity Momentum	-15.5	-0.08	-3.1	-10.4	-0.5	1.4	-2.9	17.3	12.7	-4.6	-0.7	6.9	2.3	4.0
Equity Low Vol	7.4	0.04	-13.0	-1.0	3.6	13.9	4.0	17.5	20.5	3.0	0.4	6.8	5.8	1.6
Equity Size	-11.7	-0.08	1.7	2.5	-7.3	-2.3	-6.2	23.3	33.9	10.6	2.1	5.1	8.9	11.3
Equity Volatility	43.6	0.18	4.0	11.9	13.2	5.2	9.3	14.2	13.8	-0.4	0.0	8.4	4.0	0.0
Credit Value	27.7	0.10	-7.1	-2.8	13.2	9.1	15.4	12.5	12.2	-0.4	0.0	9.5	4.0	0.0
Credit Carry	21.7	0.10	2.1	6.6	2.7	10.3	-0.1	15.1	20.1	5.0	0.6	7.9	7.5	6.1
Credit Momentum	40.3	0.08	-12.1	10.4	15.2	8.4	18.4	6.7	4.6	-2.1	-0.1	17.9	2.0	5.4
Credit Volatility	32.2	0.36	2.4	11.2	11.0	1.2	6.3	38.3	40.9	2.6	0.8	3.1	4.8	0.3
Rates Value	35.1	0.52	2.3	13.2	8.0	4.6	7.0	51.2	48.3	-2.9	-1.2	2.3	3.8	0.2
Rates Carry	29.9	0.11	-7.6	9.9	5.8	17.7	4.2	12.6	7.7	-4.9	-0.5	9.4	1.6	8.2
Rates Momentum	34.7	0.37	2.9	21.4	2.7	5.1	2.5	36.5	53.5	17.0	5.2	3.3	9.1	11.9
Rates Volatility	16.3	0.10	5.0	0.7	7.5	1.1	1.9	22.0	26.7	4.7	0.9	5.4	6.2	2.5
FX Value	21.1	0.49	0.9	10.9	2.9	4.4	2.0	79.3	66.2	-13.2	-8.8	1.5	2.9	1.5
FX Carry	-21.6	-0.09	5.9	11.8	-22.5	5.3	-22.2	13.9	18.4	4.5	0.5	8.6	7.4	5.7
FX Momentum	2.0	0.01	-3.5	-1.2	6.4	1.9	-1.6	11.8	6.4	-5.4	-0.5	10.1	1.3	11.4
FX Volatility	37.8	0.30	9.2	5.7	10.8	6.2	6.0	27.0	26.4	-0.5	-0.1	4.4	4.1	0.0
Commodity Value	36.8	0.15	3.0	12.1	24.4	-4.3	1.6	14.3	13.1	-1.2	-0.1	8.3	3.6	0.4
Commodity Carry	46.9	0.40	9.7	8.2	12.8	6.3	9.9	29.1	37.7	8.7	2.1	4.1	7.1	4.9
Commodity Momentum	34.8	0.09	12.6	5.9	5.6	-9.0	19.7	9.1	5.6	-3.5	-0.3	13.1	1.6	8.1
Commodity Volatility	71.6	0.40	-5.0	8.2	35.8	0.8	31.9	19.2	14.9	-4.3	-0.7	6.2	2.6	2.7

Source: J.P. Morgan Quantitative and Derivatives Strategy

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Equity Value

Figure 25: Equity Value

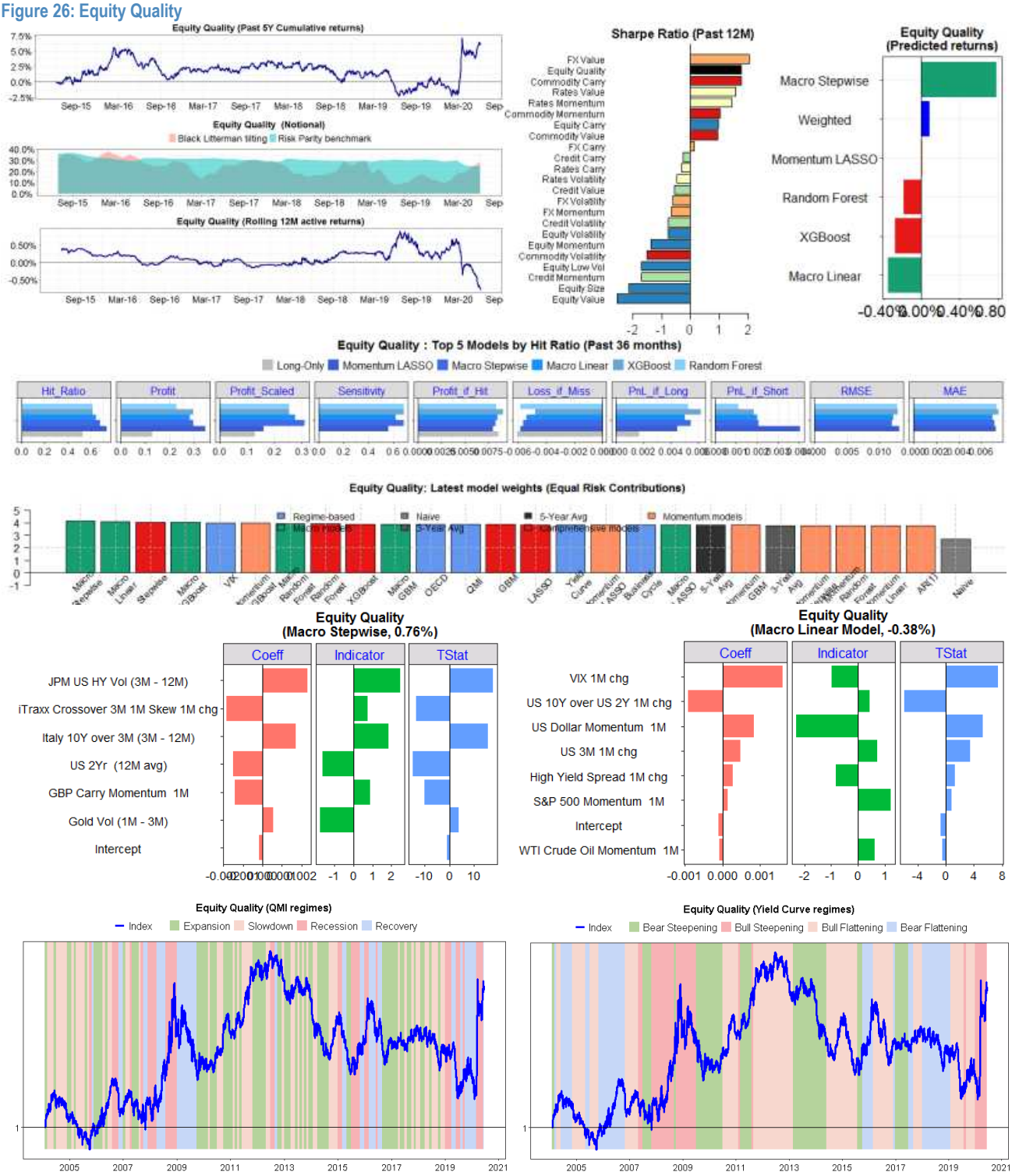


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Equity Quality

Figure 26: Equity Quality

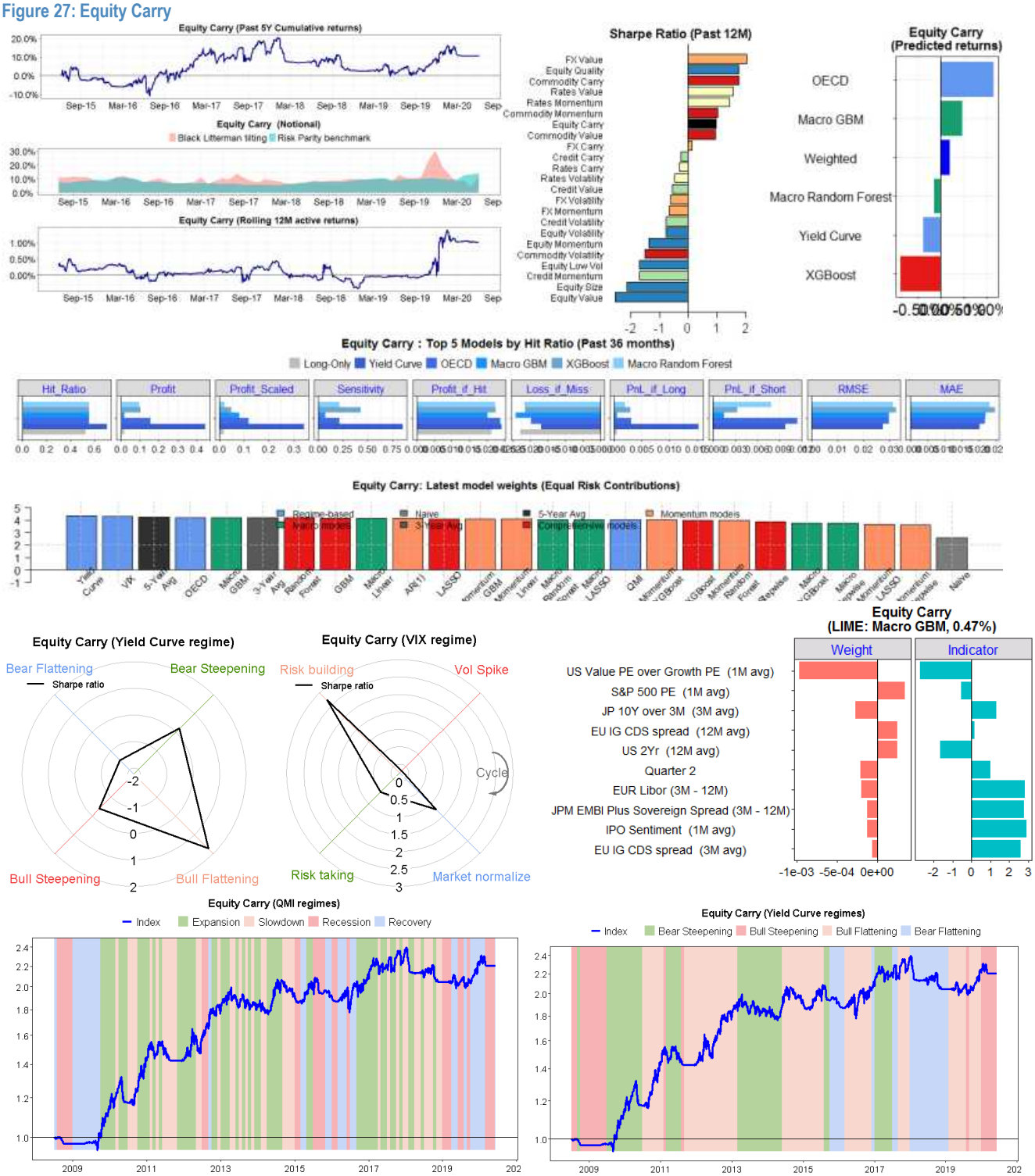


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Equity Carry

Figure 27: Equity Carry

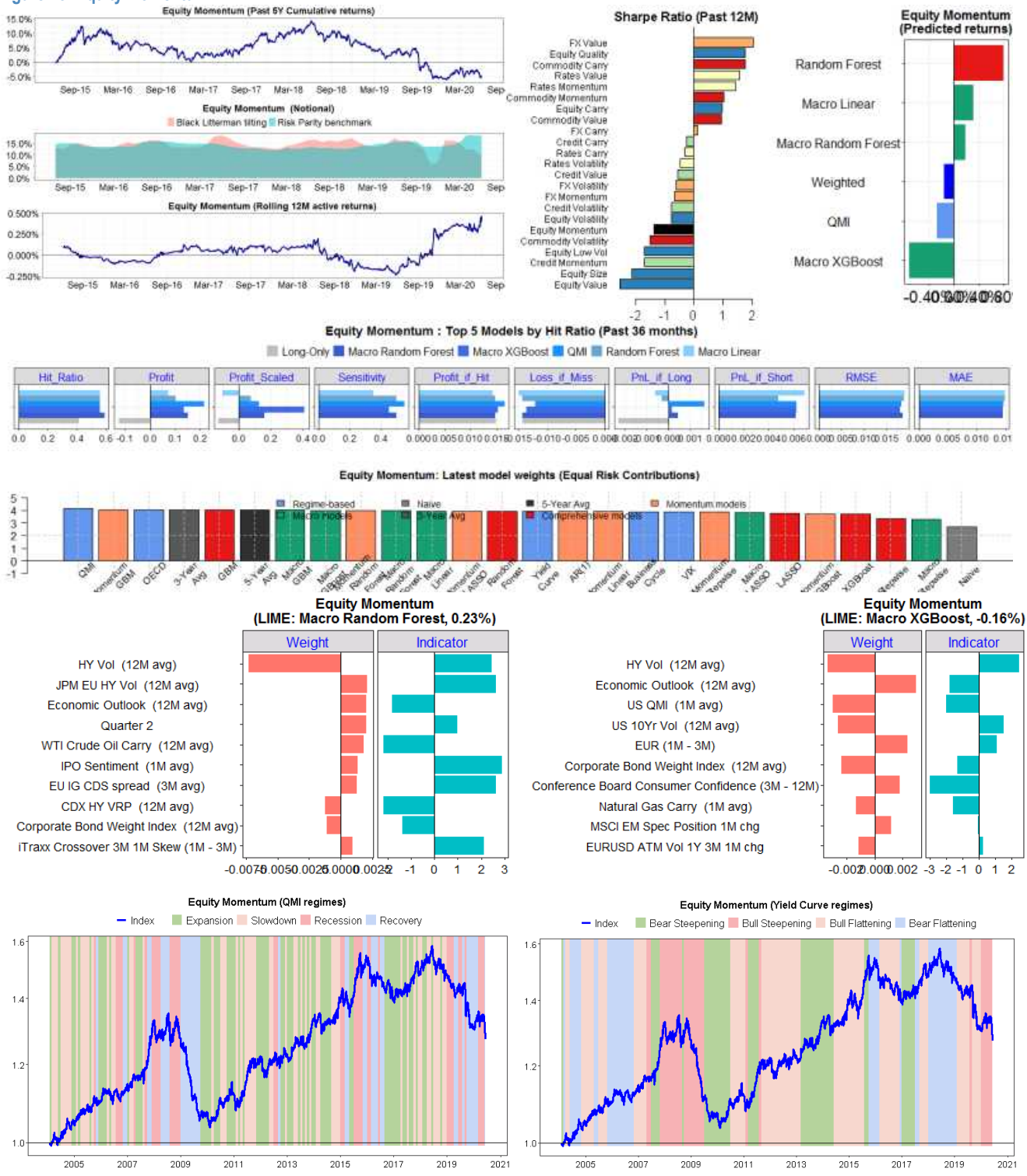


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Equity Momentum

Figure 28: Equity Momentum

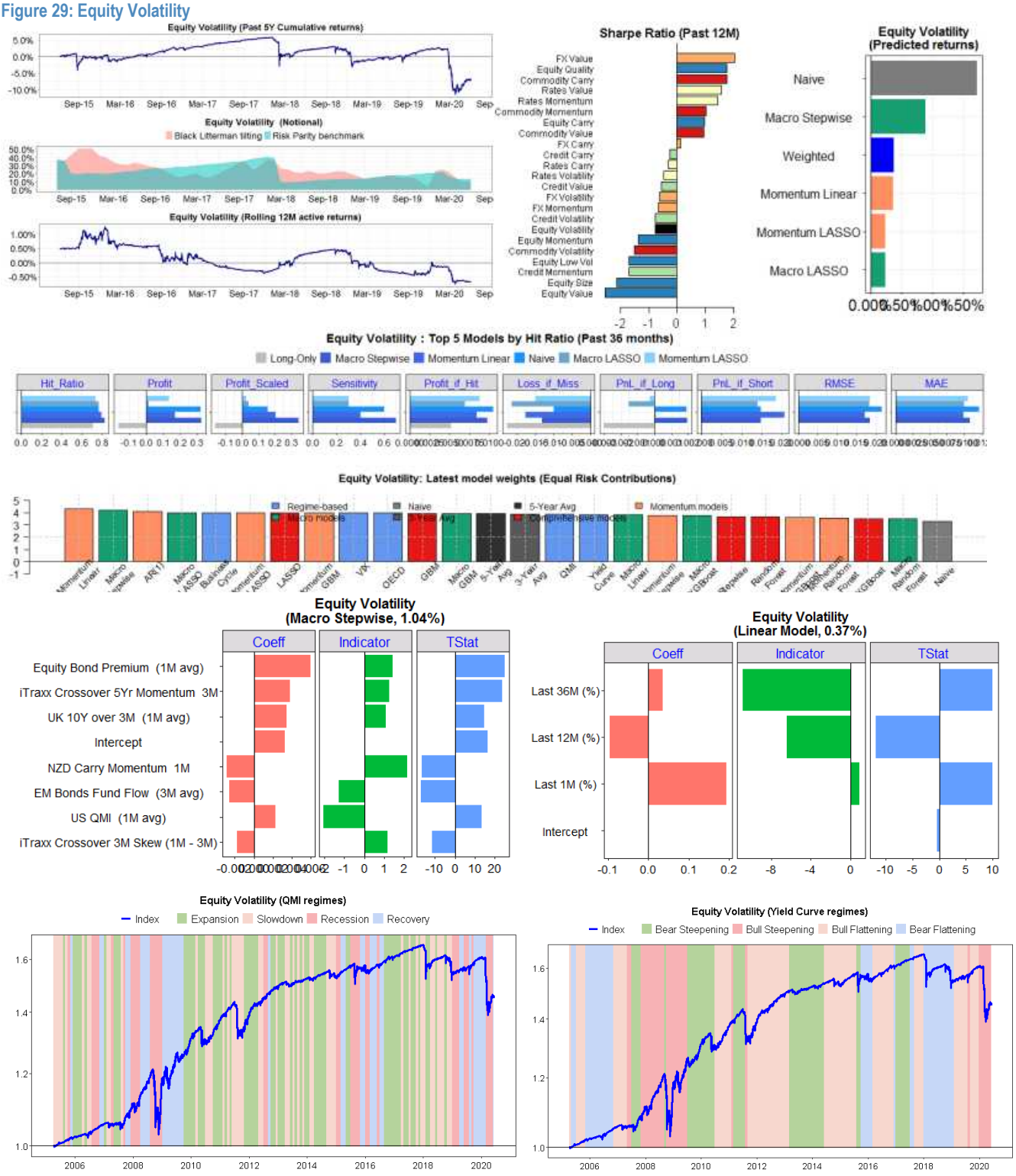


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Equity Volatility

Figure 29: Equity Volatility



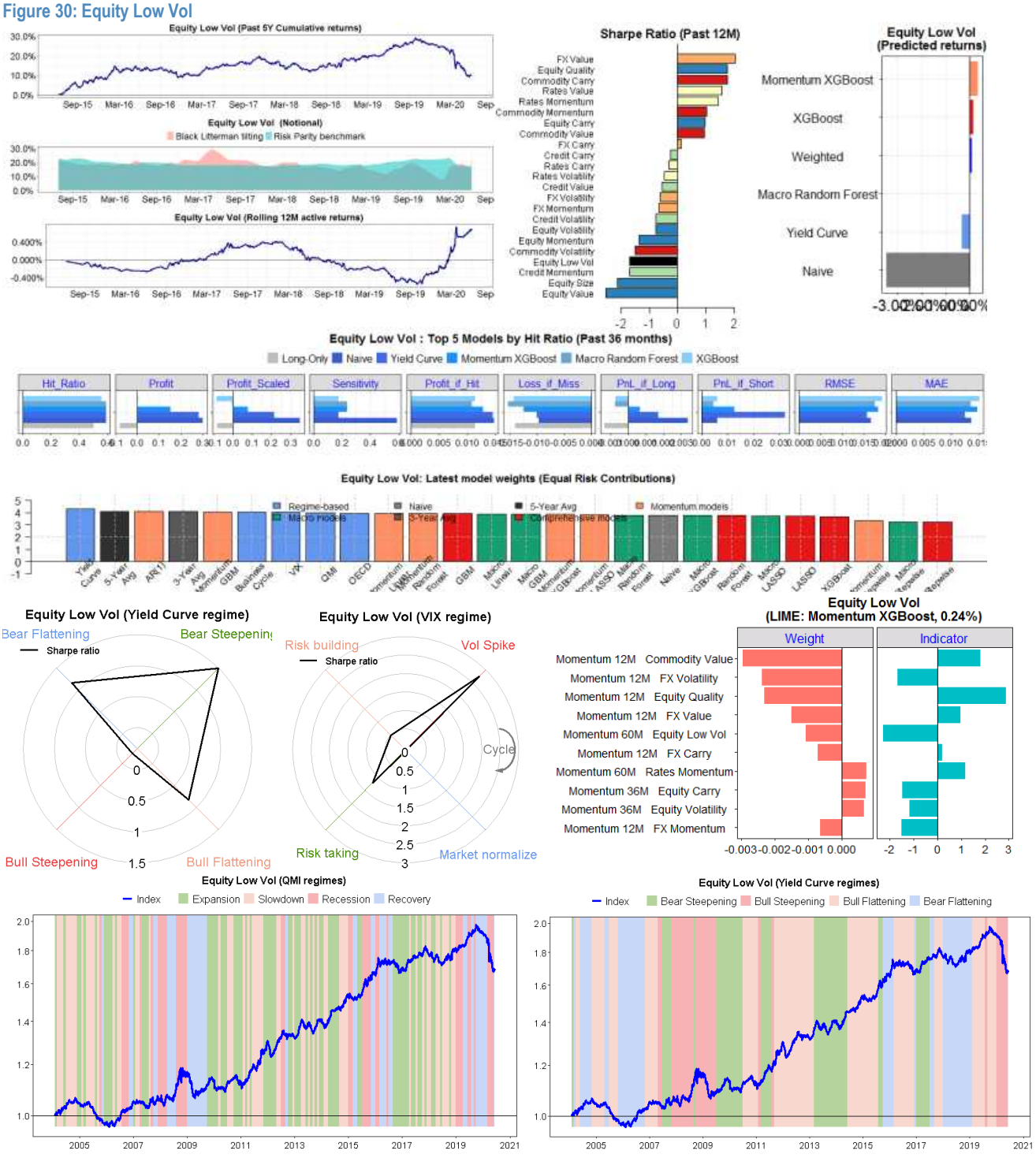
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Equity Low Vol

Figure 30: Equity Low Vol



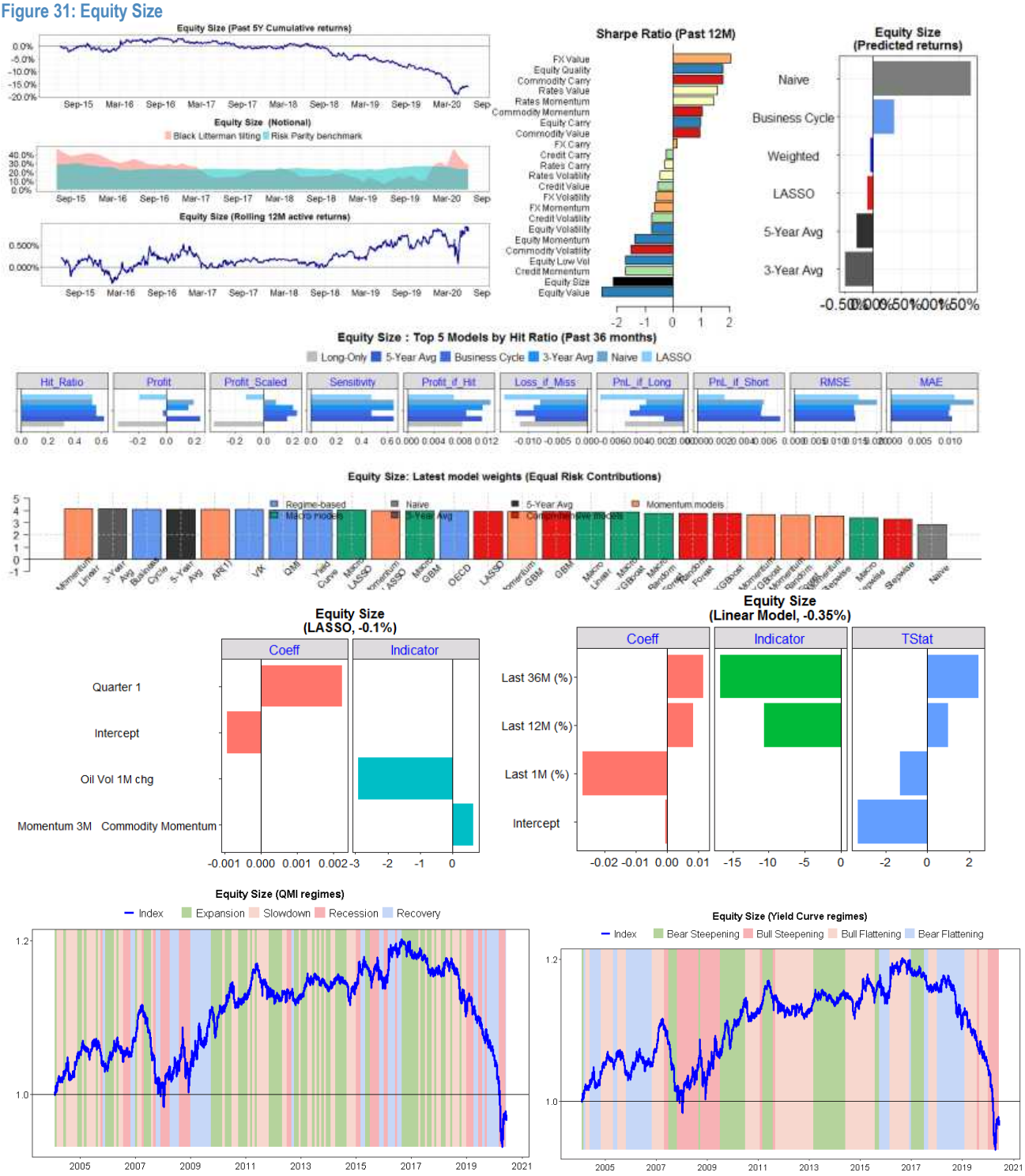
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Equity Size

Figure 31: Equity Size



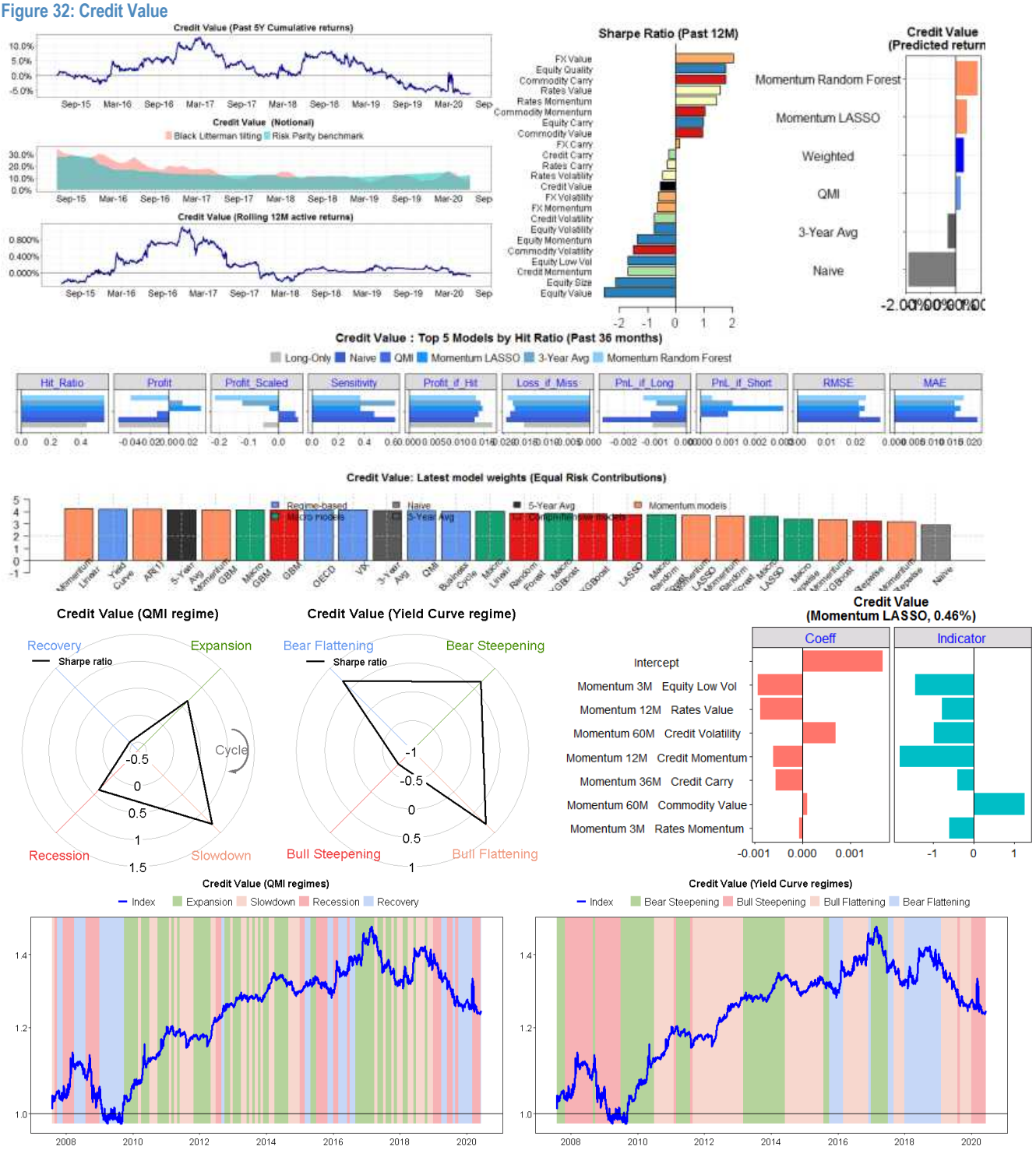
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Credit Value

Figure 32: Credit Value

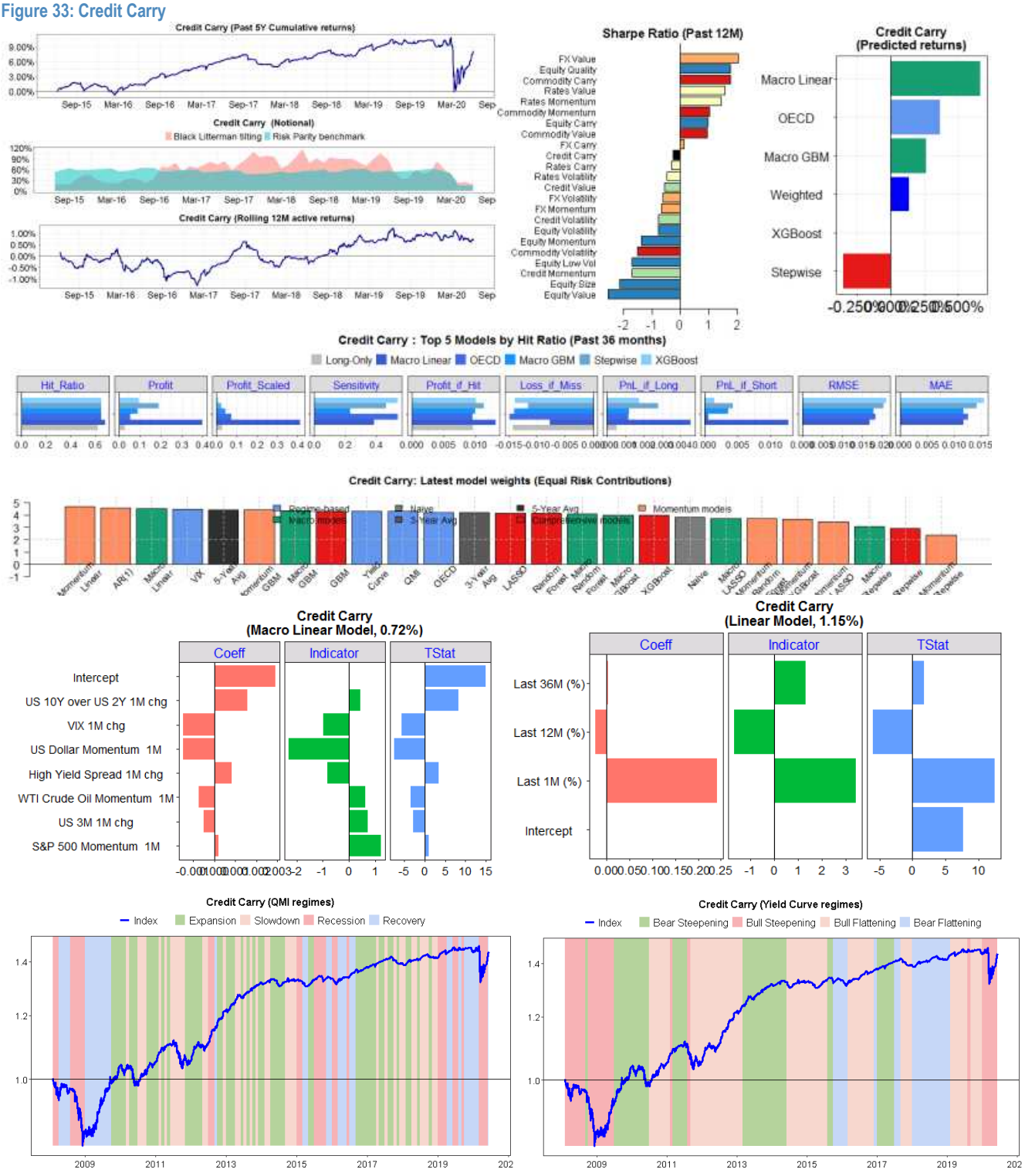


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Credit Carry

Figure 33: Credit Carry



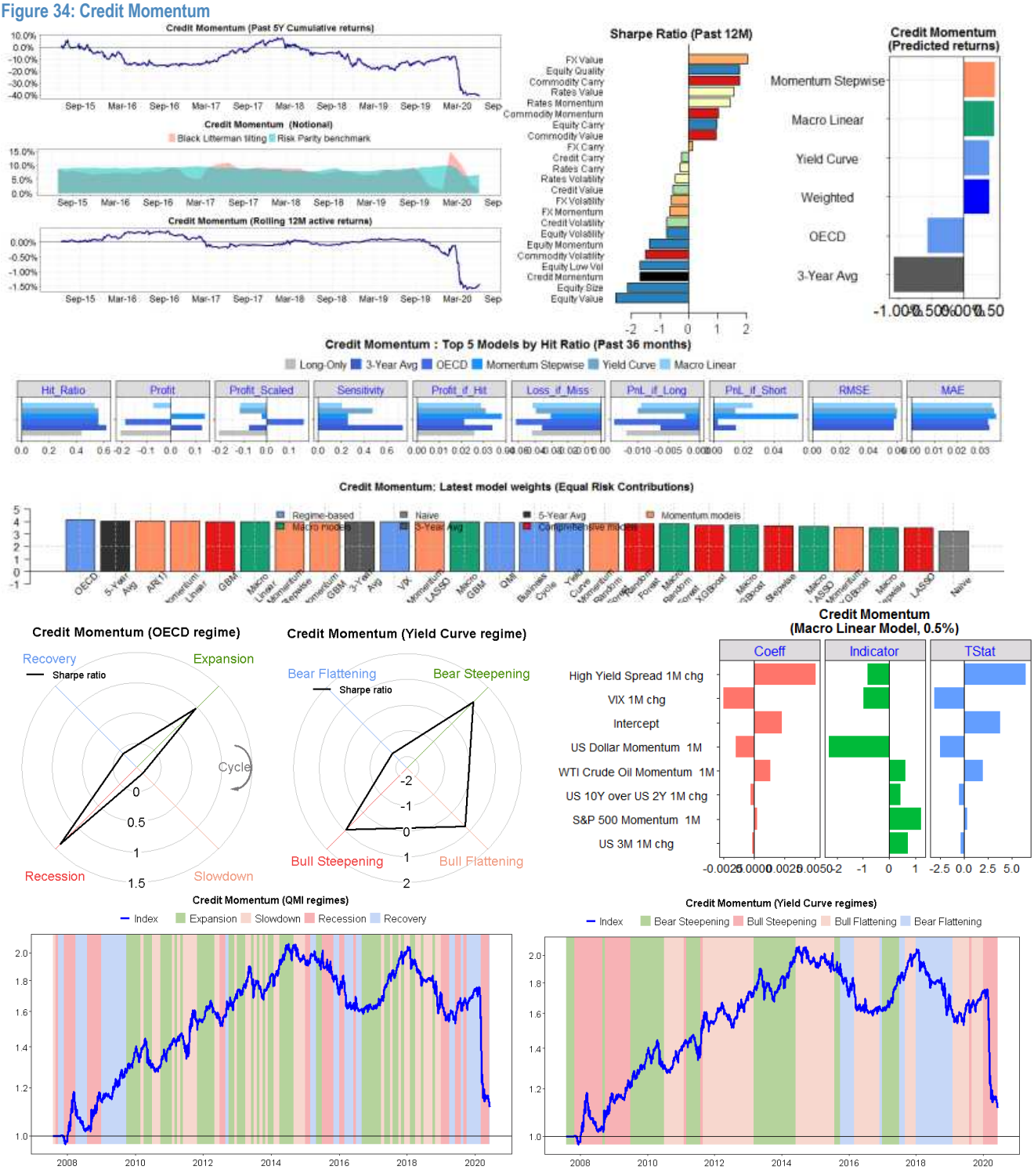
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Credit Momentum

Figure 34: Credit Momentum



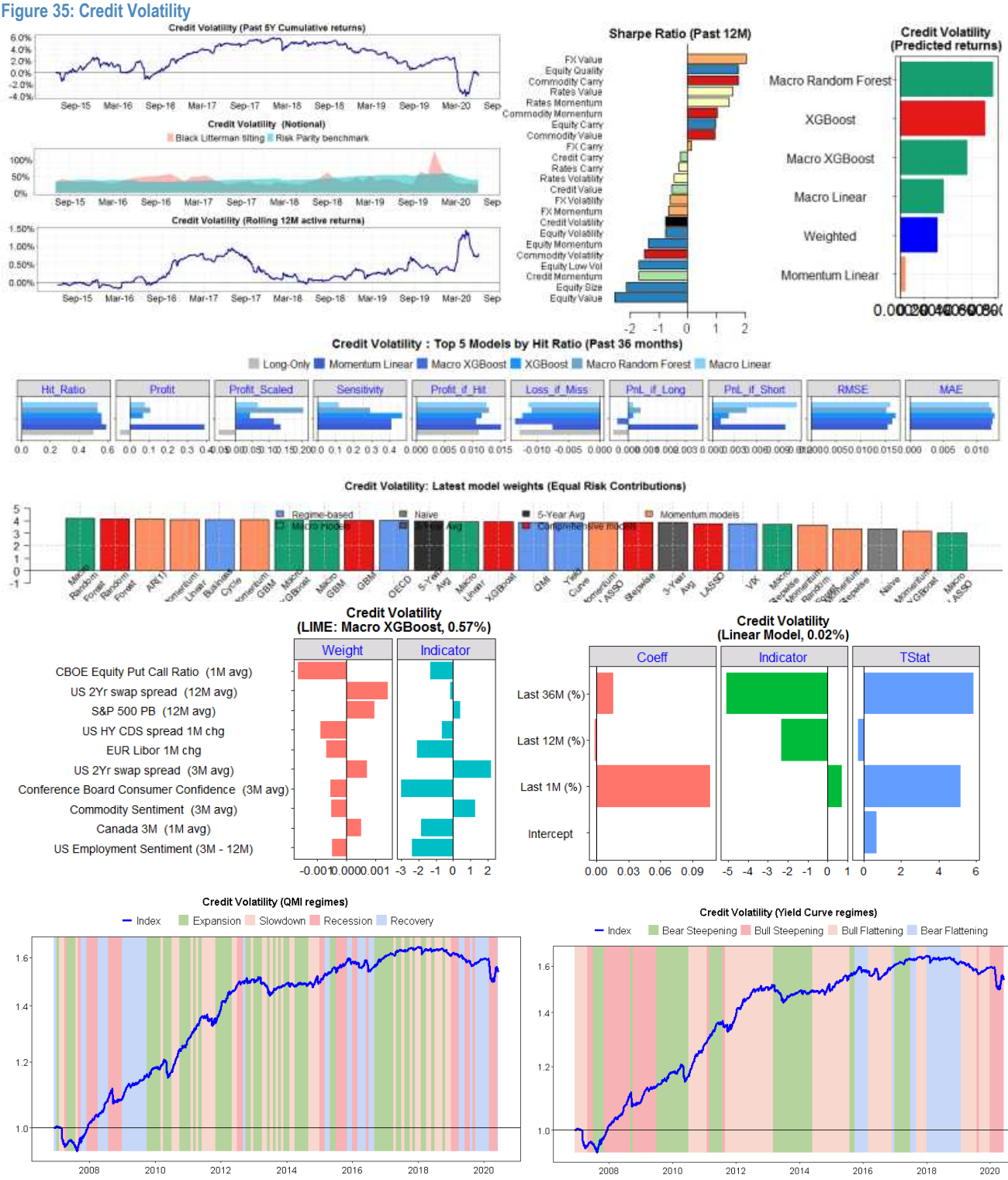
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Credit Volatility

Figure 35: Credit Volatility

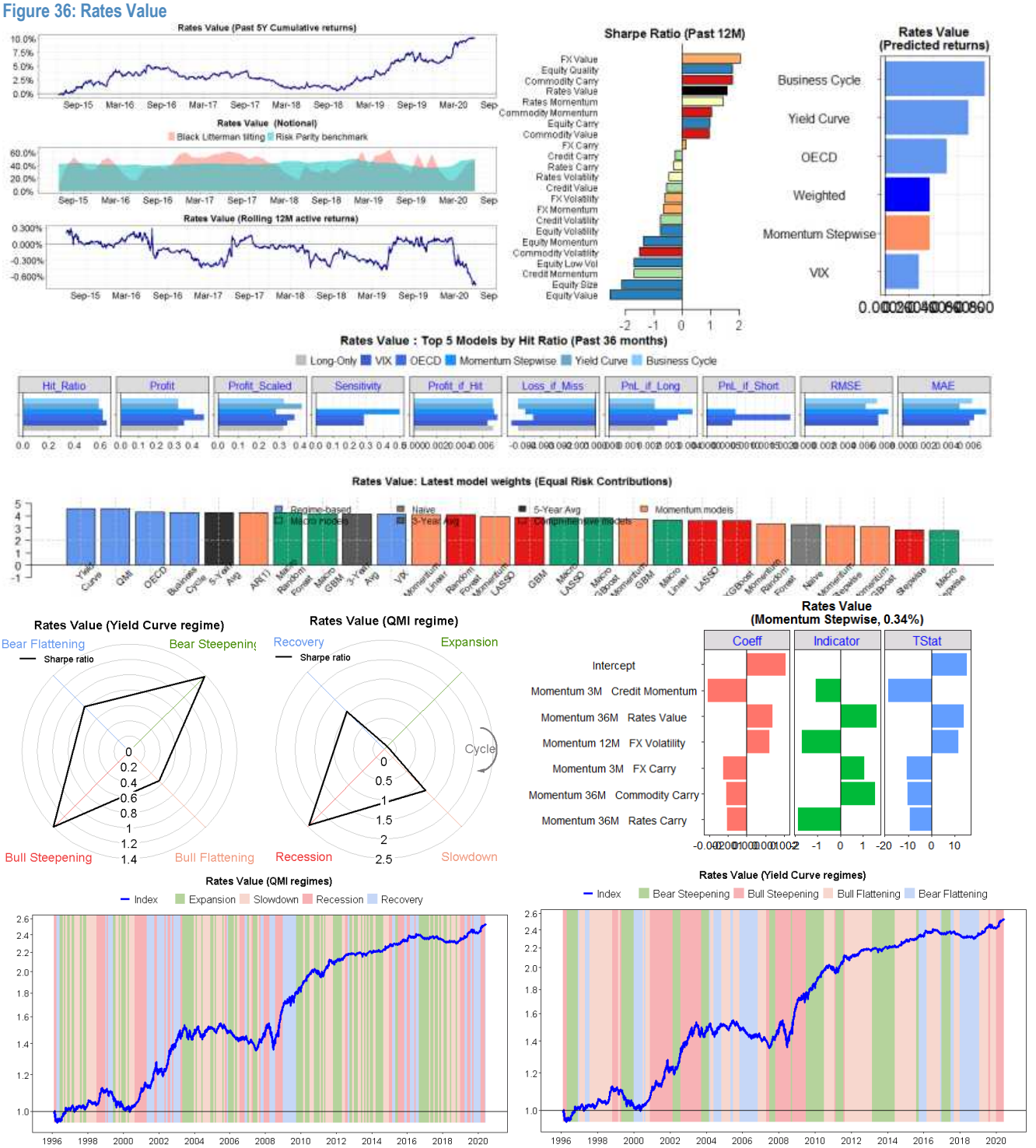


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Rates Value

Figure 36: Rates Value



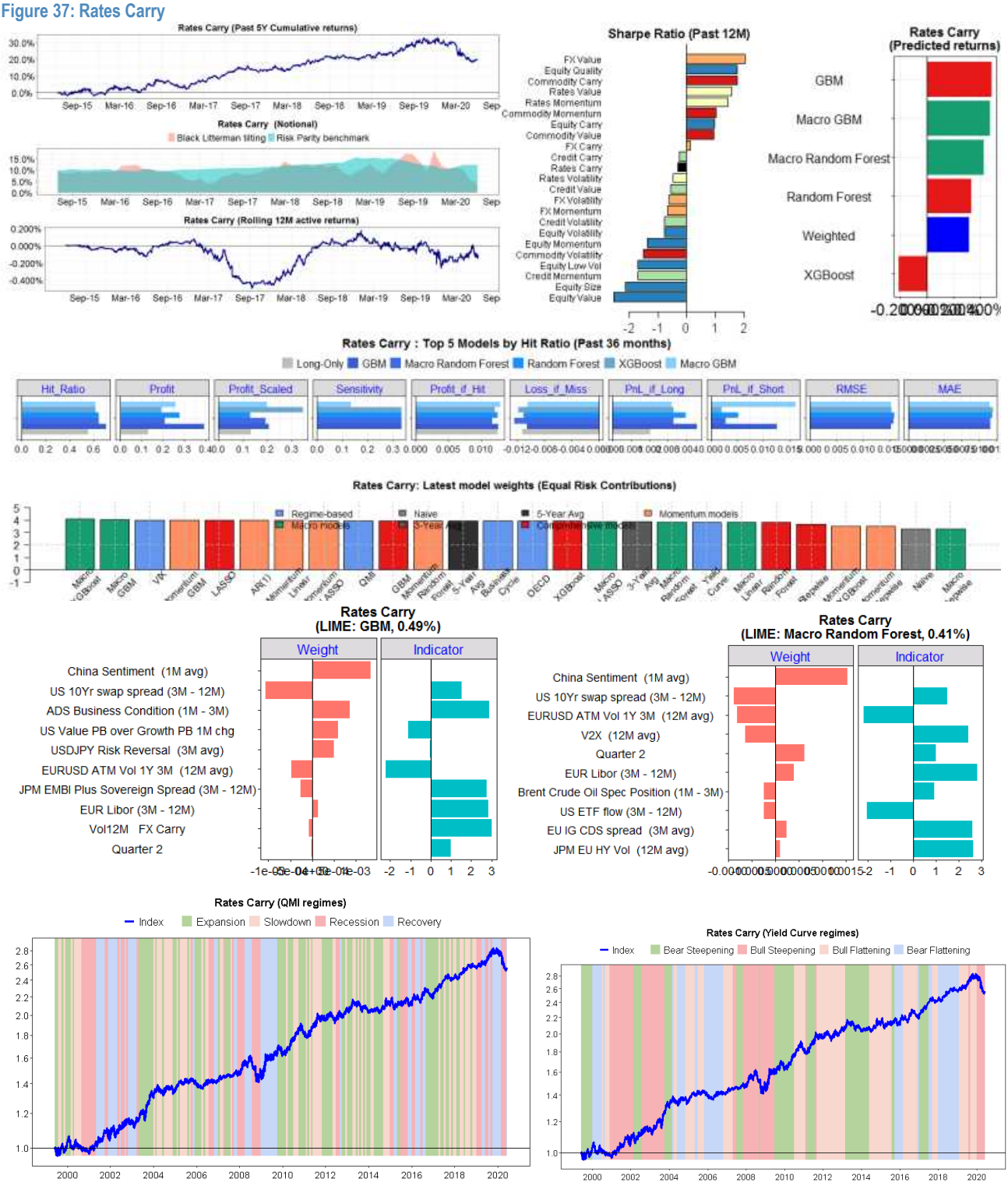
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Rates Carry

Figure 37: Rates Carry

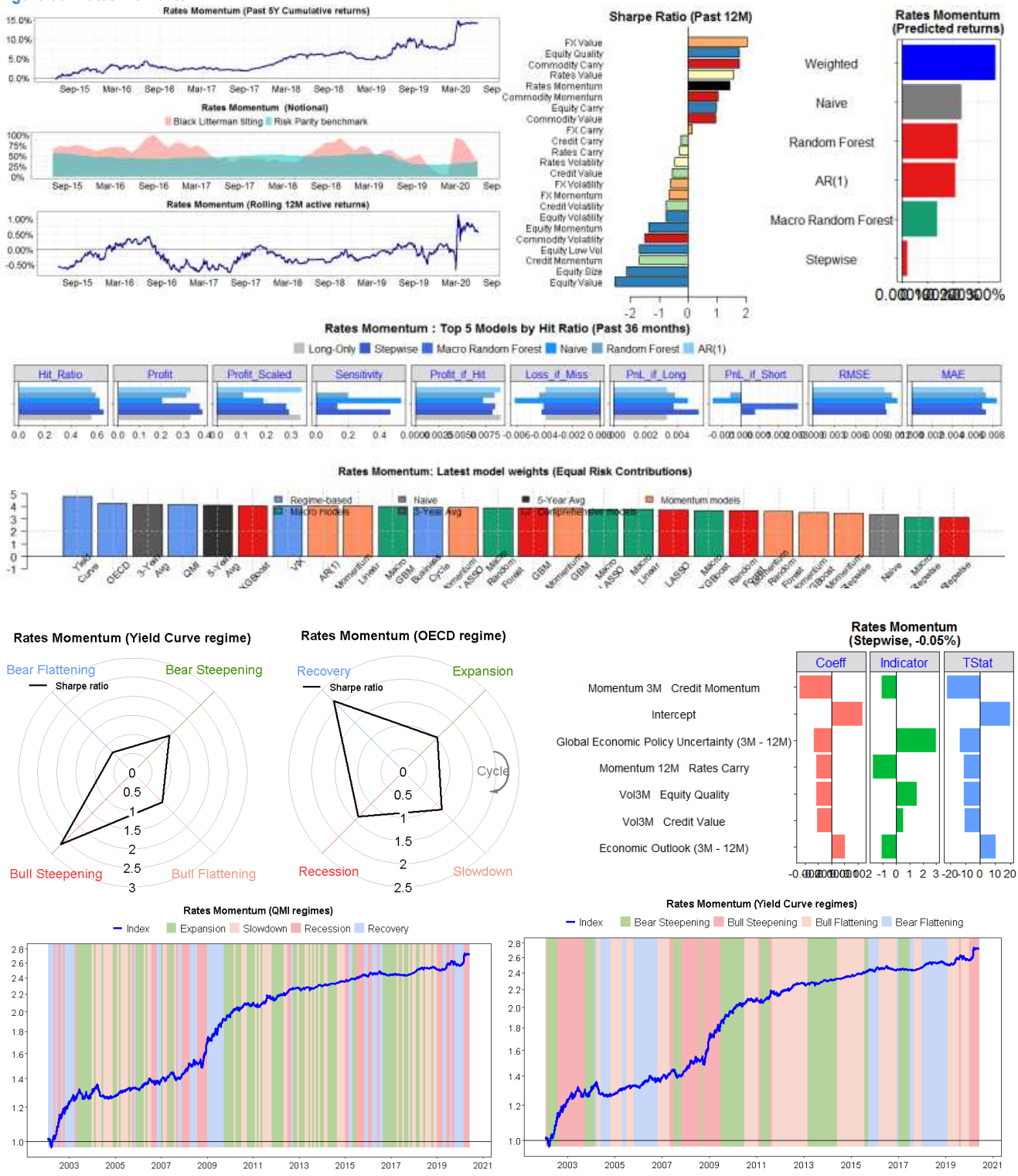


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Rates Momentum

Figure 38: Rates Momentum

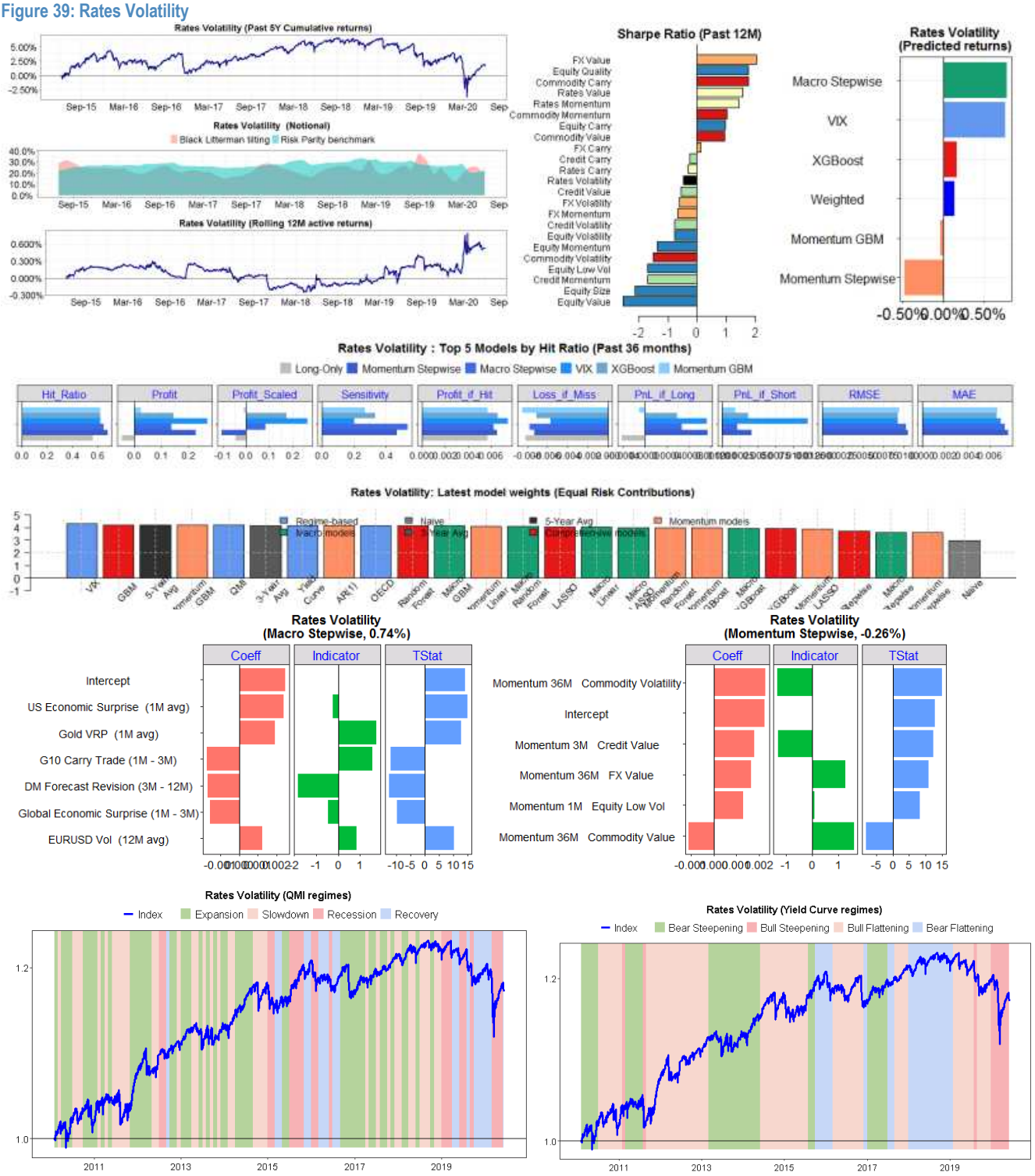


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Rates Volatility

Figure 39: Rates Volatility

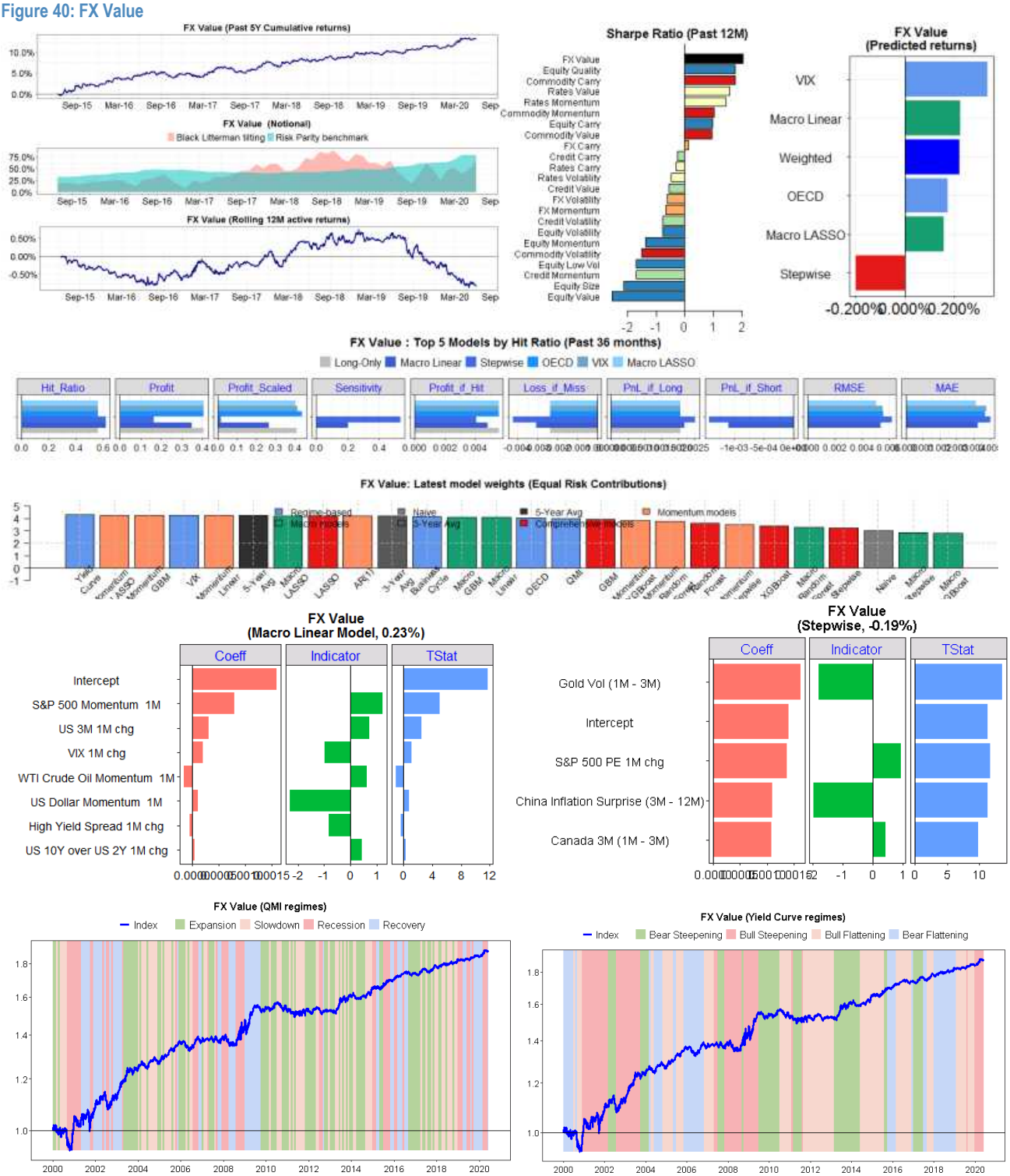


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

FX Value

Figure 40: FX Value



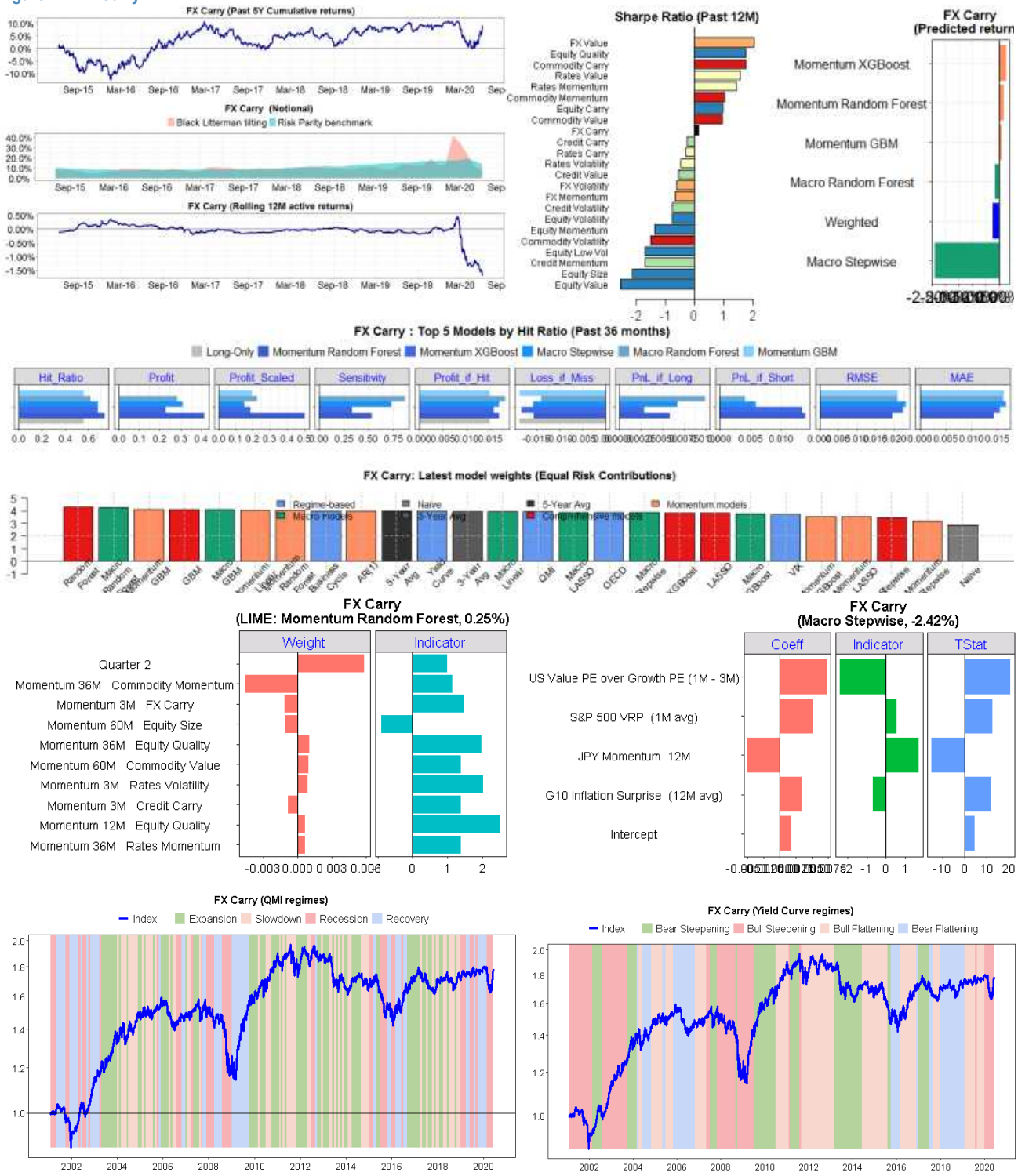
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

FX Carry

Figure 41: FX Carry



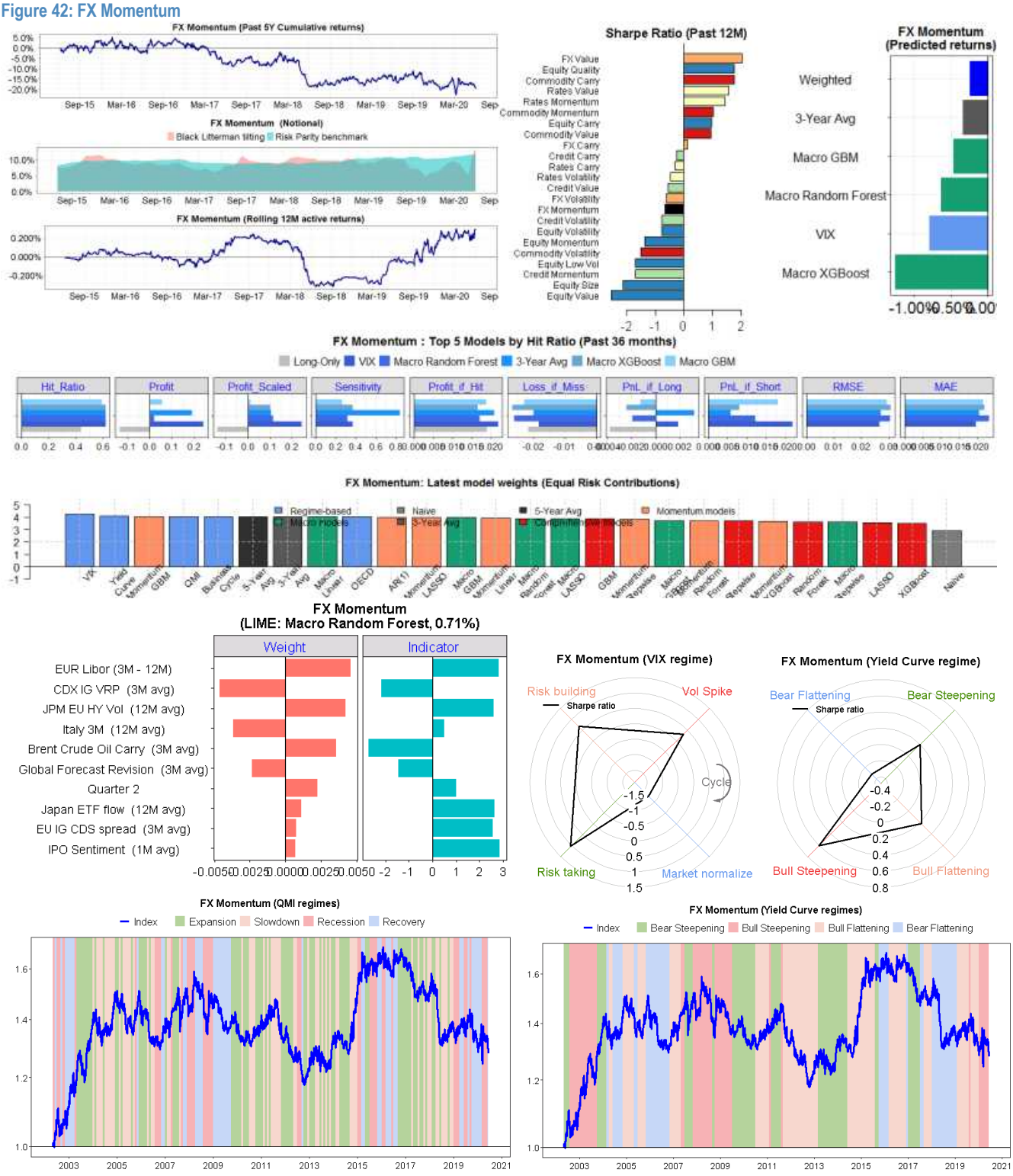
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

FX Momentum

Figure 42: FX Momentum

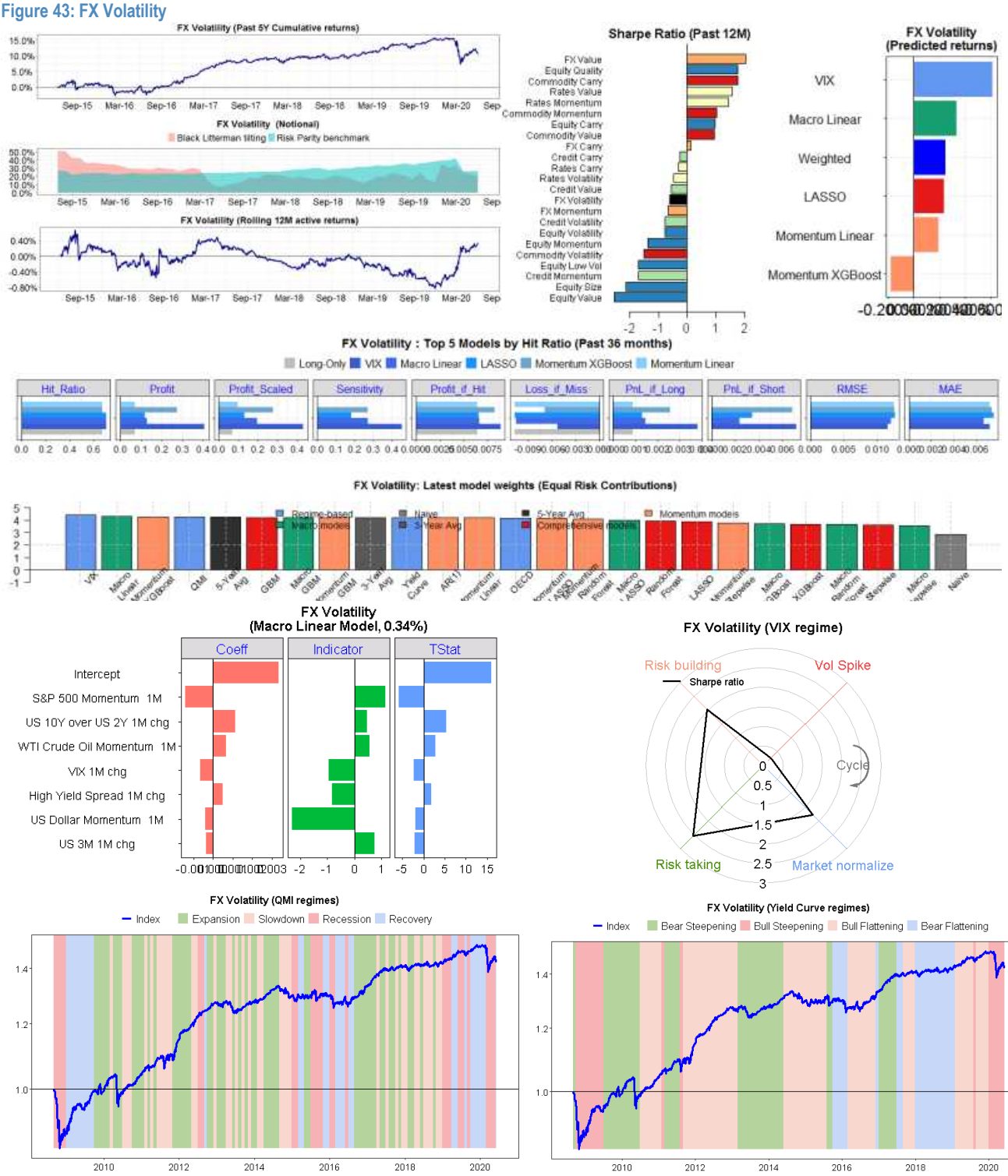


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

FX Volatility

Figure 43: FX Volatility



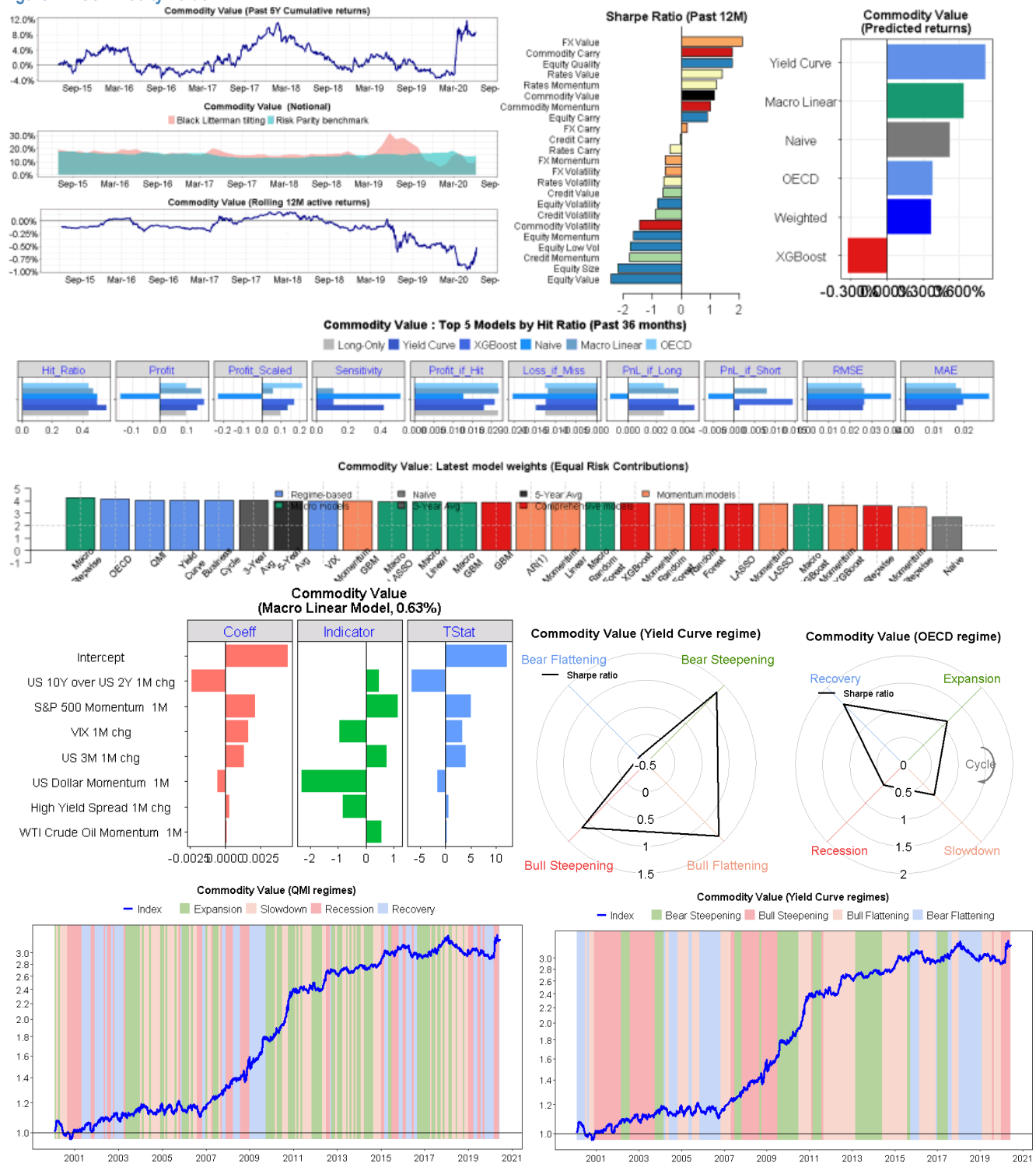
Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P.Morgan

Commodity Value

Figure 44: Commodity Value

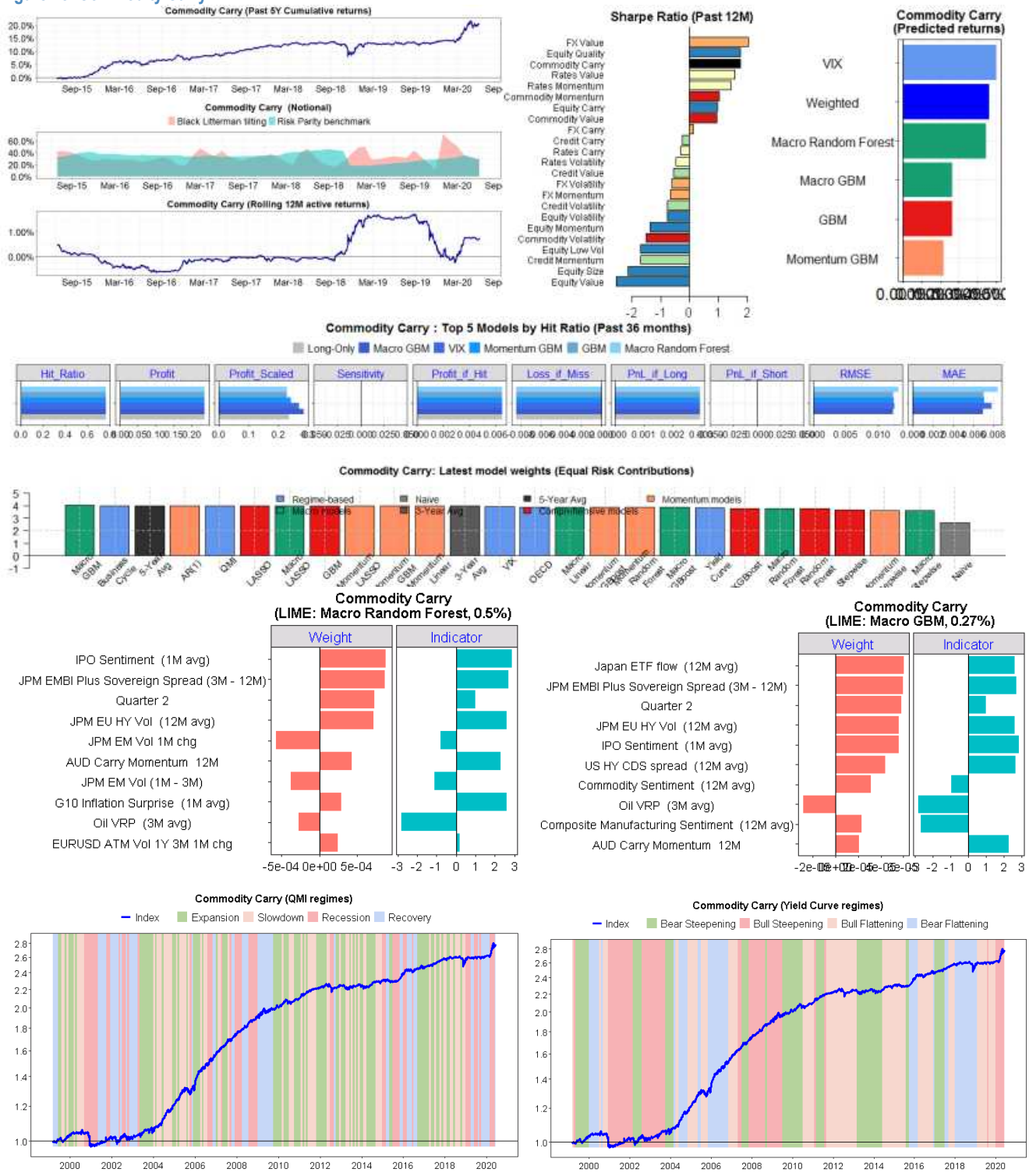


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Commodity Carry

Figure 45: Commodity Carry

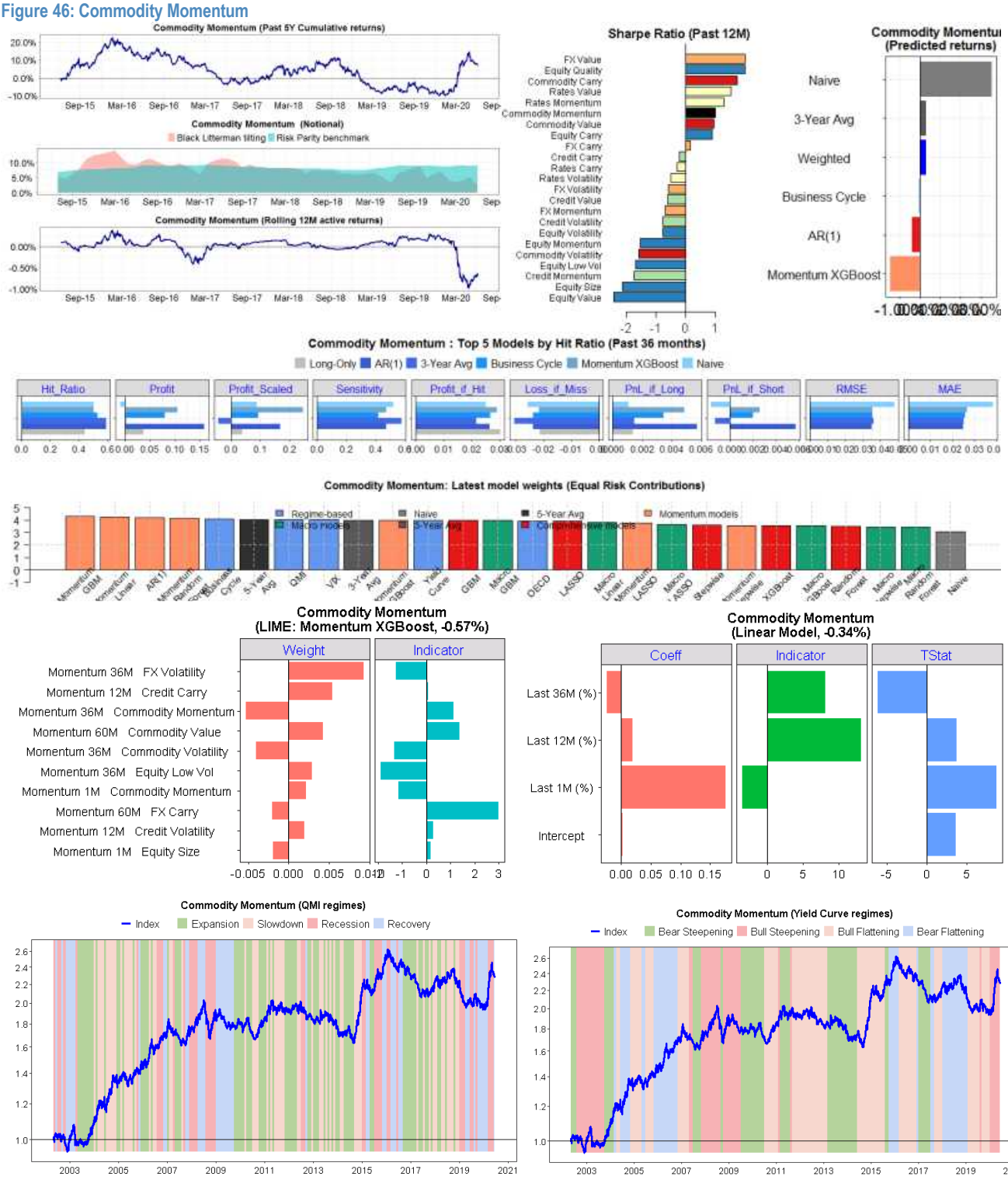


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Commodity Momentum

Figure 46: Commodity Momentum

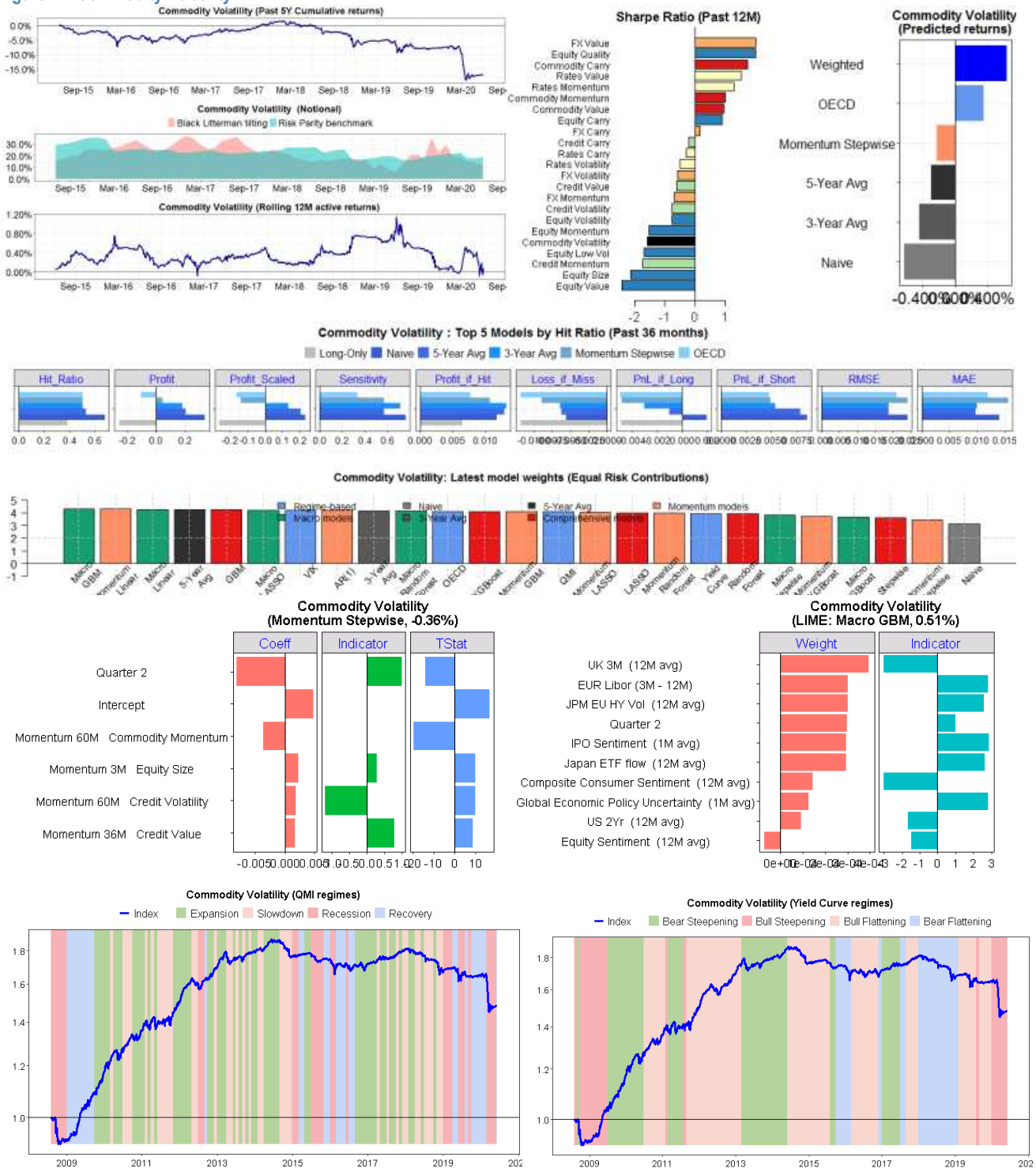


Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Commodity Volatility

Figure 47: Commodity Volatility



Source: J.P. Morgan Quantitative and Derivatives Strategy; Bloomberg; RavenPack; EPFR

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

Past Issues and Relevant Reports

Quantitative Perspectives on Cross-Asset Risk Premia

12 May 2020: Higher Moments 'Aware' Portfolio Construction Techniques and Update on Market-Neutral Carry Performance

09 April 2020: Update on Defensive Strategies, COVID vs GFC, Monitoring Recession Pattern and Latest Model Views

05 March 2020: Impacts from market shocks, growth revisions and falling rates, and latest model views

17 January 2020: Reviewing 2019 Performance, Raw vs Pure Equity Factors and Latest Model Views

4 October 2019: New Suite of Market-neutral Carry indices, Value/Momentum rotation and Latest Model Views

5 June 2019: Implications from Macro Outlook, Timing Equity Styles with Crowdedness Signal and Latest Model Views

17 April 2019: Yield Curve Regimes, Performance Attributions for Pure ERPs and Latest Model Views

6 March 2019: Macro-Economic Backdrop, Liquidity in Equity Styles and Tail Risk Parity

18 January 2019: Business cycle, crowdedness measures for equity styles, and implications of the JPM Equity Outlook

6 December, 2018: Risk premia sensitivity to rates/equities, implications of JPM 2019 FICC outlooks and our latest timing forecasts

Systematic Cross Asset Risk Premia Strategies

Tzotchev, D. et al (2020) Defensive Risk Premia: Systematic Strategies for the Risk-Off Times J.P. Morgan Global Quantitative and Derivatives Strategy, 11 March 2020

Lau, A. et al (2019) Custom Performance Attribution based on Portfolio Holdings: Decomposing Risk and Return Drivers via Factor-Mimicking Portfolios J.P. Morgan Global Quantitative and Derivatives Strategy, 3 December 2019

Tzotchev, D. et al (2019) The quest for pure equity factor exposure: How to eliminate the unwanted biases in equity factors? J.P. Morgan Global Cross-Asset Risk Premia Strategy, 28 November 2019

Ravagli, L. et al (2018) Optimal option delta-hedging: Uncovering the link between mean-reversion and options strategies across markets, J.P. Morgan Global Quantitative and Derivatives Strategy, 15 November 2018

Tzotchev, D. et al (2018) Market-neutral carry strategies: Harvesting carry without market risk, J.P. Morgan Global Quantitative & Derivatives Strategy, 4 October 2018

Lau, A. et al (2018) A Quantitative Framework for Cross-asset Style Timing: Machine Learning, Macro and Time-Series models providing views for Portfolio Tilting, J.P. Morgan Global Quantitative and Derivatives Strategy, 03 October 2018

Tzotchev, D. et al (2018) Designing robust trend-following system: Behind the scenes of trend-following, J.P. Morgan Global Quantitative & Derivatives Strategy, 6 February 2018

Lau, A. et al (2018) Harvesting Volatility Risk Premia With Machine Learning: Volatility Spread Strategy Using Dynamic Linear Model, J.P. Morgan Global Quantitative and Derivatives Strategy, 31 January 2018

Lau, A. et al (2017) Cross-asset Portfolios of Tradable Risk Premia Indices: Hierarchical Risk Parity: Enhancing Returns at Target, J.P. Morgan Global Quantitative and Derivatives Strategy, 26 April 2017

Lau, A. et al (2017) Value Strategies based on Machine Learning: Incorporating Profitability Measure and Sentiment Signals to Identify Winners and Losers, J.P. Morgan Global Quantitative and Derivatives Strategy, 08 August 2017

Risk Premia Primers

Kolanovic, M. and Wei, Z. (2013) Systematic Strategies Across Asset Classes: Risk Factor Approach to Investing and Portfolio Management, J.P. Morgan Quantitative and Derivative Strategy

Kolanovic, M. and Wei, Z. (2014) Equity Risk Premia Strategies: Risk Factor Approach to Portfolio Management. J.P. Morgan Global Quantitative and Derivatives Research, September 2014

Kolanovic, M. and Wei, Z. (2015) Momentum Strategies Across Asset Classes: Risk Factor Approach to Trend Following. J.P. Morgan Global Quantitative and Derivatives Research, April 2015

Ada Lau
(852) 2800-7618
ada.lau@jpmorgan.com

J.P. Morgan Cross-Asset Risk Premia Indices

Table 1: J.P. Morgan cross-asset risk premia Indices. We apply t-costs and running fee assumptions when we rebalance the indices in our portfolio

Name	Asset	Style	Ticker	Strategy overview
Equity				
J.P. Morgan Equity Risk Premium – Global Pure Value	Equity	Value	JPQGVLW2	L/S strategy on Value factor
J.P. Morgan Equity Risk Premium – Global Pure Quality	Equity	Quality	JPQGQUW2	L/S strategy on Quality factor
J.P. Morgan US Volatility Term Premia Index	Equity	Carry	JPMZVP4G	Systematic long puts on VIX Futures
J.P. Morgan Equity Risk Premium – Global Pure Momentum	Equity	Momentum	JPQGMOW2	L/S strategy on Momentum factor
J.P. Morgan Equity Risk Premium – Global Pure Low Vol	Equity	Low Vol	JPQGLVW2	L/S strategy on Low Vol factor
J.P. Morgan Equity Risk Premium – Global Pure Size	Equity	Size	JPQGSZW2	L/S strategy on Size factor
J.P. Morgan US 5% Mean Reversion Short Volatility Index	Equity	Volatility	JPOSUS5M	Monetize carry between implied and realized volatility through options exposure in S&P (5% notional a day)
Credit				
J.P. Morgan Global Credit Value	Credit	Value	JCREGCV1	Aim to monetize the risk premia between major CDS indices using a fair value spread
J.P. Morgan Credit Global Curve Steepener	Credit	Carry	JCRECVSG	Track performance from a rolling 5s10s steepener on iTraxx Main and CDX IG
J.P. Morgan Global Credit Momentum USD	Credit	Momentum	JCREMOGU	Aim to capture cross-sectional momentum in global credit indices
J.P. Morgan Global HY Short Volatility	Credit	Volatility	JCRESV3H	Aim to monetize the high implied volatility relative to realized volatility in iTraxx Crossover and CDX HY options by selling straddles and delta hedging on a daily basis
Rates				
J.P. Morgan MAST Basket of 3 Index (USD)	Rates	Value	JPMSUBK3	Capture forward rate risk premium in 3-month USD, EUR and GBP Libor 1y forward
J.P. Morgan CarryMax 2 Futures-6 USD Index	Rates	Carry	JCMX2A6U	Capture yield differential in govt. bond futures
J.P. Morgan Helix 3 Index (USD)	Rates	Momentum	JHLXH3US	Capture trends in short-term interest rate markets using money market futures
J.P. Morgan JPVLBTYU Index	Rates	Volatility	JPVLBTYU	Capture value from the implied versus realized volatility of UST10Y Note futures by shorting option strangles and delta hedge
FX				
J.P. Morgan JPFCVA01 Index	FX	Value	JPFCVA01	Capture value in FX pairs in G10 using PPP
J.P. Morgan FX Carry JPFCARB1	FX	Carry	JPFCARB1	Long high yielding currencies and short low yielders on a large universe of currency pairs
J.P. Morgan JMCUFCTA Index	FX	Momentum	JMCUFCTA	Aim to extract the momentum effect from the underlying FX pairs
J.P. Morgan FX Volemont JPVOFX02 Index	FX	Volatility	JPVOFX02	Pure short gamma exposure across 5 USD currency pairs
Commodity				
J.P. Morgan Compendium Fundamental Index	Commodity	Value	JCOPCF	Using momentum on fundamental signals to go long-short commodities
J.P. Morgan Alpha Select II Index	Commodity	Carry	JMABDBSE	Capture commodity curve carry
J.P. Morgan JMCUCCTA Index	Commodity	Momentum	JMCUCCTA	Aim to extract the momentum effect from the underlying commodities
J.P. Morgan Custom JMAB279E Index	Commodity	Volatility	JMAB279E	Monetize the premium between implied and realized volatility with Breakeven Curve filter

Source: J.P. Morgan Quantitative and Derivatives Strategy

Analyst Certification: The research analyst(s) denoted by an "AC" on the cover of this report certifies (or, where multiple research analysts are primarily responsible for this report, the research analyst denoted by an "AC" on the cover or within the document individually certifies, with respect to each security or issuer that the research analyst covers in this research) that: (1) all of the views expressed in this report accurately reflect the research analyst's personal views about any and all of the subject securities or issuers; and (2) no part of any of the research analyst's compensation was, is, or will be directly or indirectly related to the specific recommendations or views expressed by the research analyst(s) in this report. For all Korea-based research analysts listed on the front cover, if applicable, they also certify, as per KOFIA requirements, that their analysis was made in good faith and that the views reflect their own opinion, without undue influence or intervention.

All authors named within this report are research analysts unless otherwise specified. In Europe, Sector Specialists may be shown on this report as contacts but are not authors of the report or part of the Research Department.

Important Disclosures

This report is a product of the research department's Global Quantitative and Derivatives Strategy group. Views expressed may differ from the views of the research analysts covering stocks or sectors mentioned in this report. Structured securities, options, futures and other derivatives are complex instruments, may involve a high degree of risk, and may be appropriate investments only for sophisticated investors who are capable of understanding and assuming the risks involved. Because of the importance of tax considerations to many option transactions, the investor considering options should consult with his/her tax advisor as to how taxes affect the outcome of contemplated option transactions.

Company-Specific Disclosures: Important disclosures, including price charts and credit opinion history tables, are available for compendium reports and all J.P. Morgan–covered companies by visiting https://www.jpmm.com/research/disclosures, calling 1-800-477-0406, or e-mailing research.disclosure.inquiries@jpmorgan.com with your request. J.P. Morgan's Strategy, Technical, and Quantitative Research teams may screen companies not covered by J.P. Morgan. For important disclosures for these companies, please call 1-800-477-0406 or e-mail research.disclosure.inquiries@jpmorgan.com.

Explanation of Equity Research Ratings, Designations and Analyst(s) Coverage Universe:
J.P. Morgan uses the following rating system: Overweight [Over the next six to twelve months, we expect this stock will outperform the average total return of the stocks in the analyst's (or the analyst's team's) coverage universe.] Neutral [Over the next six to twelve months, we expect this stock will perform in line with the average total return of the stocks in the analyst's (or the analyst's team's) coverage universe.] Underweight [Over the next six to twelve months, we expect this stock will underperform the average total return of the stocks in the analyst's (or the analyst's team's) coverage universe.] Not Rated (NR): J.P. Morgan has removed the rating and, if applicable, the price target, for this stock because of either a lack of a sufficient fundamental basis or for legal, regulatory or policy reasons. The previous rating and, if applicable, the price target, no longer should be relied upon. An NR designation is not a recommendation or a rating. In our Asia (ex-Australia and ex-India) and U.K. small- and mid-cap equity research, each stock's expected total return is compared to the expected total return of a benchmark country market index, not to those analysts' coverage universe. If it does not appear in the Important Disclosures section of this report, the certifying analyst's coverage universe can be found on J.P. Morgan's research website, www.jpmorganmarkets.com.

J.P. Morgan Equity Research Ratings Distribution, as of April 04, 2020

	Overweight (buy)	Neutral (hold)	Underweight (sell)
J.P. Morgan Global Equity Research Coverage	46%	40%	14%
IB clients*	52%	49%	37%
JPMS Equity Research Coverage	44%	42%	14%
IB clients*	75%	68%	57%

*Percentage of subject companies within each of the "buy," "hold" and "sell" categories for which J.P. Morgan has provided investment banking services within the previous 12 months. Please note that the percentages might not add to 100% because of rounding.
For purposes only of FINRA ratings distribution rules, our Overweight rating falls into a buy rating category; our Neutral rating falls into a hold rating category; and our Underweight rating falls into a sell rating category. Please note that stocks with an NR designation are not included in the table above. This information is current as of the end of the most recent calendar quarter.

Equity Valuation and Risks: For valuation methodology and risks associated with covered companies or price targets for covered companies, please see the most recent company-specific research report at http://www.jpmorganmarkets.com, contact the primary analyst or your J.P. Morgan representative, or email research.disclosure.inquiries@jpmorgan.com. For material information about the proprietary models used, please see the Summary of Financials in company-specific research reports and the Company Tearsheets, which are available to download on the company pages of our client website, http://www.jpmorganmarkets.com. This report also sets out within it the material underlying assumptions used.

Analysts' Compensation: The research analysts responsible for the preparation of this report receive compensation based upon various factors, including the quality and accuracy of research, client feedback, competitive factors, and overall firm revenues.

Registration of non-US Analysts: Unless otherwise noted, the non-US analysts listed on the front of this report are employees of non-US affiliates of J.P. Morgan Securities LLC, may not be registered as research analysts under FINRA rules, may not be associated persons of J.P. Morgan Securities LLC, and may not be subject to FINRA Rule 2241 or 2242 restrictions on communications with covered companies, public appearances, and trading securities held by a research analyst account.

Other Disclosures

J.P. Morgan is a marketing name for investment banking businesses of JPMorgan Chase & Co. and its subsidiaries and affiliates worldwide.

All research reports made available to clients are simultaneously available on our client website, J.P. Morgan Markets. Not all research content is redistributed, e-mailed or made available to third-party aggregators. For all research reports available on a particular stock, please contact your sales representative.

Any data discrepancies in this report could be the result of different calculations and/or adjustments.

Any long form nomenclature for references to China; Hong Kong; Taiwan; and Macau within this research report are Mainland China; Hong Kong SAR, China; Taiwan, China; Macau SAR, China.

Options and Futures related research: If the information contained herein regards options or futures related research, such information is available only to persons who have received the proper options or futures risk disclosure documents. Please contact your J.P. Morgan Representative or visit https://www.theocc.com/components/docs/riskstoc.pdf for a copy of the Option Clearing Corporation's Characteristics and Risks of Standardized Options or http://www.finra.org/sites/default/files/Security_Futures_Risk_Disclosure_Statement_2018.pdf for a copy of the Security Futures Risk Disclosure Statement.

Changes to Interbank Offered Rates (IBORs) and other benchmark rates: Certain interest rate benchmarks are, or may in the future become, subject to ongoing international, national and other regulatory guidance, reform and proposals for reform. For more information, please consult: https://www.jpmorgan.com/global/disclosures/interbank_offered_rates

Principal Trading: J.P. Morgan trades or may trade as principal in the derivatives or the debt securities (or related derivatives) that are the subject of this report.

Private Bank Clients: Where you are receiving research as a client of the private banking businesses offered by JPMorgan Chase & Co. and its subsidiaries ("J.P. Morgan Private Bank"), research is provided to you by J.P. Morgan Private Bank and not by any other division of J.P. Morgan, including but not limited to the J.P. Morgan corporate and investment bank and its research division.

Legal entity responsible for the production of research: The legal entity identified below the name of the Reg AC research analyst who authored this report is the legal entity responsible for the production of this research. Where multiple Reg AC research analysts authored this report with different legal entities identified below their names, these legal entities are jointly responsible for the production of this research.

Legal Entities Disclosures
U.S.: JPMS is a member of NYSE, FINRA, SIPC and the NFA. JPMorgan Chase Bank, N.A. is a member of FDIC. **Canada**: J.P. Morgan Securities Canada Inc. is a registered investment dealer, regulated by the Investment Industry Regulatory Organization of Canada and the Ontario Securities Commission and is the participating member on Canadian exchanges. **U.K**.: JPMorgan Chase N.A., London Branch, is authorised by the Prudential Regulation Authority and is subject to regulation by the Financial Conduct Authority and to limited regulation by the Prudential Regulation Authority. Details about the extent of our regulation by the Prudential Regulation Authority are available from J.P. Morgan on request. J.P. Morgan Securities plc (JPMS plc) is a member of the London Stock Exchange and is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority. Registered in England & Wales No. 2711006. Registered Office 25 Bank Street, London, E14 5JP. **Germany**: This material is distributed in Germany by J.P. Morgan Securities plc, Frankfurt Branch which is regulated by the Bundesanstalt für Finanzdienstleistungsaufsich and also by J.P. Morgan AG (JPM AG) which is a member of the Frankfurt stock exchange and is regulated by the Federal Financial Supervisory Authority (BaFin), JPM AG is a company incorporated in the Federal Republic of Germany with registered office at Taunustor 1, 60310 Frankfurt am Main, the Federal Republic of Germany. **South Africa**: J.P. Morgan Equities South Africa Proprietary Limited is a member of the Johannesburg Securities Exchange and is regulated by the Financial Services Board. **Hong Kong**: J.P. Morgan Securities (Asia Pacific) Limited (CE number AAJ321) is regulated by the Hong Kong Monetary Authority and the Securities and Futures Commission in Hong Kong and/or J.P. Morgan Broking (Hong Kong) Limited (CE number AAB027) is regulated by the Securities and Futures Commission in Hong Kong. JP Morgan Chase Bank, N.A., Hong Kong is organized under the laws of U.S.A. with limited liability. **China**: J.P. Morgan Securities (China) Company Limited has been approved by CSRC to conduct the securities investment consultancy business. **Korea**: This material is issued and distributed in Korea by or through J.P. Morgan Securities (Far East) Limited, Seoul Branch, which is a member of the Korea Exchange(KRX) and is regulated by the Financial Services Commission (FSC) and the Financial Supervisory Service (FSS). **Australia**: J.P. Morgan Securities Australia Limited (JPMSAL) (ABN 61 003 245 234/AFS Licence No: 238066) is regulated by ASIC and is a Market, Clearing and Settlement Participant of ASX Limited and CHI-X. **Taiwan**: J.P. Morgan Securities (Taiwan) Limited is a participant of the Taiwan Stock Exchange (company-type) and regulated by the Taiwan Securities and Futures Bureau. **India:** J.P. Morgan India Private Limited (Corporate Identity Number - U67120MH1992FTC068724), having its registered office at J.P. Morgan Tower, Off. C.S.T. Road, Kalina, Santacruz - East, Mumbai – 400098, is registered with Securities and Exchange Board of India (SEBI) as a 'Research Analyst' having registration number INH000001873. J.P. Morgan India Private Limited is also registered with SEBI as a member of the National Stock Exchange of India Limited and the Bombay Stock Exchange Limited (SEBI Registration Number – INZ000239730) and as a Merchant Banker (SEBI Registration Number - MB/INM000002970). Telephone: 91-22-6157 3000, Facsimile: 91-22-6157 3990 and Website: www.jpmipl.com. For non local research reports, this

material is not distributed in India by J.P. Morgan India Private Limited. **Thailand**: This material is issued and distributed in Thailand by JPMorgan Securities (Thailand) Ltd., which is a member of the Stock Exchange of Thailand and is regulated by the Ministry of Finance and the Securities and Exchange Commission and its registered address is 3rd Floor, 20 North Sathorn Road, Silom, Bangrak, Bangkok 10500. **Indonesia**: PT J.P. Morgan Sekuritas Indonesia is a member of the Indonesia Stock Exchange and is regulated by the OJK a.k.a. BAPEPAM LK. **Philippines**: J.P. Morgan Securities Philippines Inc. is a Trading Participant of the Philippine Stock Exchange and a member of the Securities Clearing Corporation of the Philippines and the Securities Investor Protection Fund. It is regulated by the Securities and Exchange Commission. **Brazil**: Banco J.P. Morgan S.A. is regulated by the Comissao de Valores Mobiliarios (CVM) and by the Central Bank of Brazil. **Mexico**: J.P. Morgan Casa de Bolsa, S.A. de C.V., J.P. Morgan Grupo Financiero is a member of the Mexican Stock Exchange and authorized to act as a broker dealer by the National Banking and Securities Exchange Commission. **Singapore:** This material is issued and distributed in Singapore by or through J.P. Morgan Securities Singapore Private Limited (JPMSS) [MCI (P) 018/04/2020 and Co. Reg. No.: 199405335R], which is a member of the Singapore Exchange Securities Trading Limited and/or JPMorgan Chase Bank, N.A., Singapore branch (JPMCB Singapore) [MCI (P) 070/09/2019], both of which are regulated by the Monetary Authority of Singapore. This material is issued and distributed in Singapore only to accredited investors, expert investors and institutional investors, as defined in Section 4A of the Securities and Futures Act, Cap. 289 (SFA). This material is not intended to be issued or distributed to any retail investors or any other investors that do not fall into the classes of "accredited investors," "expert investors" or "institutional investors," as defined under Section 4A of the SFA. Recipients of this document are to contact JPMSS or JPMCB Singapore in respect of any matters arising from, or in connection with, the document. **Japan**: JPMorgan Securities Japan Co., Ltd. and JPMorgan Chase Bank, N.A., Tokyo Branch are regulated by the Financial Services Agency in Japan. **Malaysia**: This material is issued and distributed in Malaysia by JPMorgan Securities (Malaysia) Sdn Bhd (18146-X) which is a Participating Organization of Bursa Malaysia Berhad and a holder of Capital Markets Services License issued by the Securities Commission in Malaysia. **Pakistan**: J. P. Morgan Pakistan Broking (Pvt.) Ltd is a member of the Karachi Stock Exchange and regulated by the Securities and Exchange Commission of Pakistan. **Dubai**: JPMorgan Chase Bank, N.A., Dubai Branch is regulated by the Dubai Financial Services Authority (DFSA) and its registered address is Dubai International Financial Centre - Building 3, Level 7, PO Box 506551, Dubai, UAE. **Russia:** CB J.P. Morgan Bank International LLC is regulated by the Central Bank of Russia. **Argentina:** JPMorgan Chase Bank Sucursal Buenos Aires is regulated by Banco Central de la República Argentina ("BCRA"- Central Bank of Argentina) and Comisión Nacional de Valores ("CNV"- Argentinian Securities Commission")

Country and Region Specific Disclosures

U.K. and European Economic Area (EEA): Unless specified to the contrary, issued and approved for distribution in the U.K. and the EEA by JPMS plc. Investment research issued by JPMS plc has been prepared in accordance with JPMS plc's policies for managing conflicts of interest arising as a result of publication and distribution of investment research. Many European regulators require a firm to establish, implement and maintain such a policy. Further information about J.P. Morgan's conflict of interest policy and a description of the effective internal organisations and administrative arrangements set up for the prevention and avoidance of conflicts of interest is set out at the following link https://www.jpmorgan.com/jpmpdf/1320742677360.pdf. This report has been issued in the U.K. only to persons of a kind described in Article 19 (5), 38, 47 and 49 of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005 (all such persons being referred to as "relevant persons"). This document must not be acted on or relied on by persons who are not relevant persons. Any investment or investment activity to which this document relates is only available to relevant persons and will be engaged in only with relevant persons. In other EEA countries, the report has been issued to persons regarded as professional investors (or equivalent) in their home jurisdiction. **Australia:** This material is issued and distributed by JPMSAL in Australia to "wholesale clients" only. This material does not take into account the specific investment objectives, financial situation or particular needs of the recipient. The recipient of this material must not distribute it to any third party or outside Australia without the prior written consent of JPMSAL. For the purposes of this paragraph the term "wholesale client" has the meaning given in section 761G of the Corporations Act 2001. J.P. Morgan's research coverage universe spans listed securities across the ASX All Ordinaries index, securities listed on offshore markets, unlisted issuers and investment products which Research management deem to be relevant to the investor base from time to time. J.P. Morgan seeks to cover companies of relevance to the domestic and international investor base across all GIC sectors, as well as across a range of market capitalisation sizes. **Germany:** This material is distributed in Germany by J.P. Morgan Securities plc, Frankfurt Branch which is regulated by the Bundesanstalt für Finanzdienstleistungsaufsicht. **Korea:** This report may have been edited or contributed to from time to time by affiliates of J.P. Morgan Securities (Far East) Limited, Seoul Branch. **Singapore:** As at the date of this report, JPMSS is a designated market maker for certain structured warrants listed on the Singapore Exchange where the underlying securities may be the securities discussed in this report. Arising from its role as designated market maker for such structured warrants, JPMSS may conduct hedging activities in respect of such underlying securities and hold or have an interest in such underlying securities as a result. The updated list of structured warrants for which JPMSS acts as designated market maker may be found on the website of the Singapore Exchange Limited: http://www.sgx.com. In addition, JPMSS and/or its affiliates may also have an interest or holding in any of the securities discussed in this report – please see the Important Disclosures section above. For securities where the holding is 1% or greater, the holding may be found in the Important Disclosures section above. For all other securities mentioned in this report, JPMSS and/or its affiliates may have a holding of less than 1% in such securities and may trade them in ways different from those discussed in this report. Employees of JPMSS and/or its affiliates not involved in the preparation of this report may have investments in the securities (or derivatives of such securities) mentioned in this report and may trade them in ways different from those discussed in this report. **Taiwan**: Research relating to equity securities is issued and distributed in Taiwan by J.P. Morgan Securities (Taiwan) Limited, subject to the license scope and the applicable laws and the regulations in Taiwan. According to Paragraph 2, Article 7-1 of Operational Regulations Governing Securities Firms Recommending Trades in Securities to Customers (as amended or supplemented) and/or other applicable laws or regulations, please note that the recipient of this material is not permitted to engage in any activities in connection with the material which may give rise to conflicts of interests, unless otherwise disclosed in the "Important Disclosures" in this material. **India:** For private circulation only, not for sale. **Pakistan:** For private circulation only, not for sale. **New Zealand:** This material is issued and distributed by JPMSAL in New Zealand only to "wholesale clients" (as defined in the Financial Advisers Act 2008). The recipient of this material must not distribute it to any third party or outside New Zealand without the prior written consent of JPMSAL. **Canada:** This report is distributed in Canada by or on behalf of J.P.Morgan Securities Canada Inc. The information contained herein is not, and under no circumstances is to be construed as an offer to sell securities described herein, or solicitation of an offer to buy securities described herein, in Canada or any province or territory thereof. The information contained herein is under no circumstances to be construed as investment advice in any province or territory of Canada and is not tailored to the needs of the recipient. **Dubai:** This report has been distributed to persons regarded as professional clients or market counterparties as defined under the DFSA rules. **Brazil:** Ombudsman J.P. Morgan: 0800-7700847 / ouvidoria.jp.morgan@jpmorgan.com.

General: Additional information is available upon request. Information has been obtained from sources believed to be reliable but JPMorgan Chase & Co. or its affiliates and/or subsidiaries (collectively J.P. Morgan) do not warrant its completeness or accuracy except with respect to any disclosures relative to JPMS and/or its affiliates and the analyst's involvement with the issuer that is the subject of the research. All pricing is indicative as of the close of market

for the securities discussed, unless otherwise stated. Opinions and estimates constitute our judgment as of the date of this material and are subject to change without notice. Past performance is not indicative of future results. This material is not intended as an offer or solicitation for the purchase or sale of any financial instrument. The opinions and recommendations herein do not take into account individual client circumstances, objectives, or needs and are not intended as recommendations of particular securities, financial instruments or strategies to particular clients. The recipient of this report must make its own independent decisions regarding any securities or financial instruments mentioned herein. JPMS distributes in the U.S. research published by non-U.S. affiliates and accepts responsibility for its contents. Periodic updates may be provided on companies/industries based on company specific developments or announcements, market conditions or any other publicly available information. Clients should contact analysts and execute transactions through a J.P. Morgan subsidiary or affiliate in their home jurisdiction unless governing law permits otherwise.

"Other Disclosures" last revised April 04, 2020.