J.P.Morgan

Global Quantitative & Derivatives Strategy
16 January 2019

Market and Volatility Commentary

Narrative vs. Flows, Liquidity-Volatility-Flows Feedback Loop, QE/QT and Liquidity

Global Quantitative and Derivatives Strategy

Marko Kolanovic, PhD AC
(1-212) 272-1438
marko.kolanovic@jpmorgan.com

Bram Kaplan, CFA
(1-212) 272-1215
bram.kaplan@jpmorgan.com

J.P. Morgan Securities LLC

Narrative vs. Flows

Since our last note, the market continued moving higher from heavily oversold levels and low investor positioning. Positioning has somewhat increased but still remains subdued (all HF beta: ~9th %ile, Volatility Targeting Beta: ~1st %ile, CTA beta ~15th %ile, Equity HF beta ~8th %ile, JPM PB HF net exposure ~7th %ile, gross exposure ~10th %ile). S&P 500 options gamma imbalance subsided from an average ~$50bn towards puts (dealers short gamma) in December to slightly long gamma now. This creates a necessary condition for market volatility to decline and continue driving equity inflows from volatility-sensitive strategies. These strategies are currently adding ~$1bn per day (e.g., volatility targeted insurance portfolios), which will accelerate if volatility stays subdued. While fixed weight portfolios (e.g., pensions) increased risk the last week of December, they may reduce risk the last week of January. Trend investors could close some shorts/add longs if the market moves a bit higher to reclaim short-term signals (e.g., 50d MA, 1M return). Two key risks that we highlighted in the past (Fed's monetary policy and trade war) have subsided, but new risks have emerged: US government shutdown and signs of additional slowdown outside the US. Risks around the upcoming earnings season are balanced, in our view. On one hand, we could see further downside for Q1 guidance, but on the other hand already reduced expectations and low positioning can result in upside moves. Low positioning could manifest itself as stocks moving higher on underwhelming results (e.g., stocks open lower and drift higher).

Bearish sentiment and narrative are currently consensus among investors, and positioning is very low. Investors should keep in mind that the narrative is often driven by price action, and price action is driven by flows and positioning. For instance, during the May-October period last year, there were strong inflows on account of declining volatility in the aftermath of the Feb-April turmoil. These flows pushed the market higher, despite negative seasonality, the fact that the trade war was escalating, and that there were expectations for a continuation of the quarterly rate hikes at the time. Once deleveraging started in Q4, stocks were moving lower regardless of the narrative (e.g., many stocks sold off on decent Q3 earnings and the market sold off after the G20 and Powell pivot). At the very end of the year, stocks first crashed and then strongly rallied on virtually no news but large flows (mutual fund selling, pension fund buying). One should keep in mind that if volatility stays low, inflows may result in the market drifting higher, which could in turn change investor sentiment and the whole market narrative.

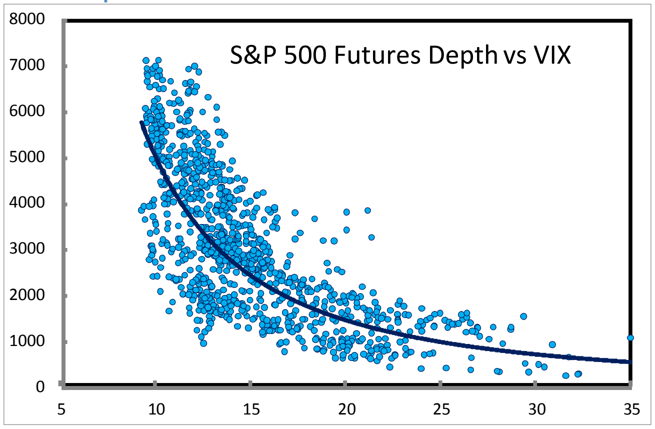
See page 7 for analyst certification and important disclosures.

Liquidity-Volatility-Flows Feedback Loop

In our previous note we described in broad terms the feedback loop between volatility, liquidity, and flows. We call this feedback loop market fragility. Several clients asked us to explain in more detail these effects (e.g., how, how much?). Interest for this topic comes from various clients – those that are assessing the impact of flows to the broad market and their portfolios (fund managers), those that position for and anticipate these flows (speculators), and those that are assessing the robustness of different systematic investments (investors). As we mentioned in our last note, systematic flows come from different parts of the financial industry (market making, buy side, insurance), and can result in different flow patterns.

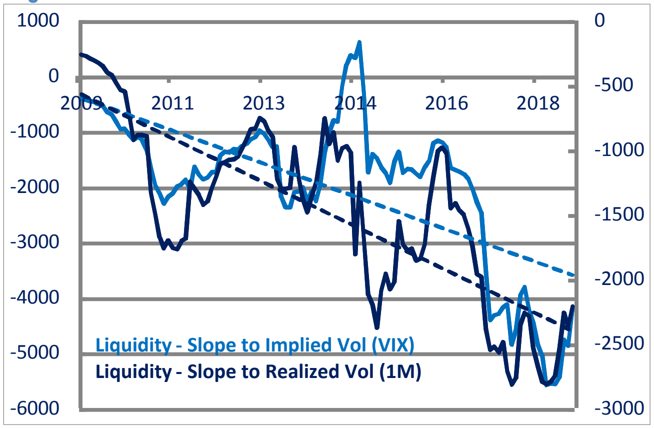
First we want to demonstrate the link between Volatility and Liquidity, and show how market depth – the key measure of liquidity – got worse over time. Figure 1 shows the relationship between S&P 500 futures market depth and the VIX. One can notice that this relationship is very strong and nonlinear (e.g., market depth declines exponentially with the VIX). Given that an increase in volatility often results in systematic selling, this relationship is the key to understand market fragility and tail events. The second question was if this relationship was always the same or the situation got worse over time. To answer this we show the historical relationship between liquidity and the VIX over time (Figure 2, rolling regression slope between liquidity and the VIX). One can see that the negative relationship between liquidity and the VIX got worse over the past decade (note that an exponential relationship can be locally approximated with a linear relationship and tracked over time). Finally, we note that at times of high volatility, the VIX is almost the sole driver of market liquidity. Figure 3 shows the % of liquidity variation that can be explained with the VIX over time (rolling R-squared). The higher the VIX, the more liquidity is driven by the VIX, and recently up to ~80% of liquidity variations were explained by the VIX. To conclude, we showed that there is a negative relationship between volatility and liquidity, that this relationship is getting stronger over time, and that it is particularly strong during times of elevated volatility.

Figure 1: S&P 500 E-mini futures depth shows a strong (exponential) relationship to the VIX



Source: J.P. Morgan QDS.

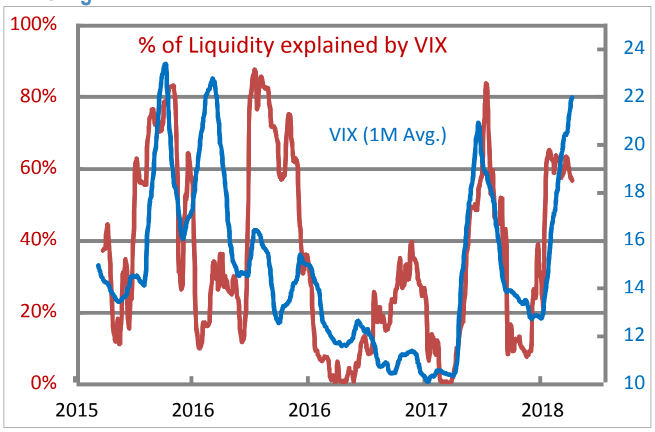
Figure 2: The regression slope between liquidity and the VIX got larger over time



Source: J.P. Morgan QDS.

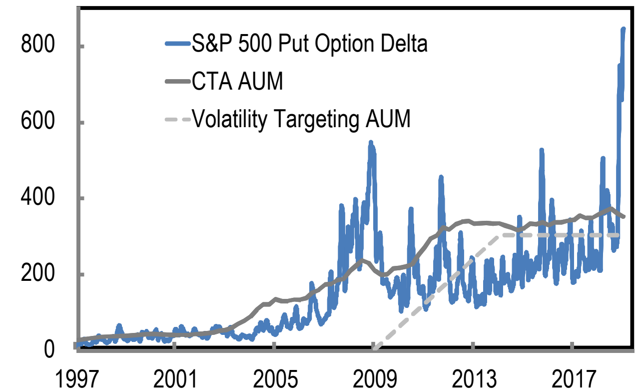
Marko Kolanovic, PhD
(1-212) 272-1438
marko.kolanovic@jpmorgan.com

Figure 3: The VIX explains a larger proportion of liquidity when the VIX is high



Source: J.P. Morgan QDS.

Figure 4: Comparative size of 'short gamma' strategies*



Source: J.P. Morgan QDS, BarclayHedge. *Volatility Targeting AUM time series is purely illustrative/very approximate

We will next show that volatility also plays a significant role in determining the flows from various systematic strategies (note that we define systematic flows to include derivatives hedging flows, passive and quantitative investment strategies flows, insurance industry and programmatic market making flows). An increase in volatility typically leads to an increase in systematic selling, which happens in an environment of reduced liquidity, and hence can produce outsized market impact. As mentioned above, we refer to this feedback loop between volatility, liquidity and flows as market fragility. We do note that during times of high volatility/low liquidity, not only systematic strategies but also discretionary managers sell, albeit typically they tend to sell slower and/or later during the sell-off episodes (see further below).

Let's look at the various examples of systematic flows, their impact on the market and their own performance, and speculative activity related to these flows. The largest of all systematic flows by size and impact is that of index options hedging. Figure 4 shows the delta weighted open interest of S&P 500 index puts, in comparison with an asset estimate of two other 'short gamma' strategies – CTAs/Trend-Following and Volatility Targeting strategies. One can see that the largest component of systematic flows comes from option hedging, but given the increase of trend-following and volatility targeting these components cannot be ignored.

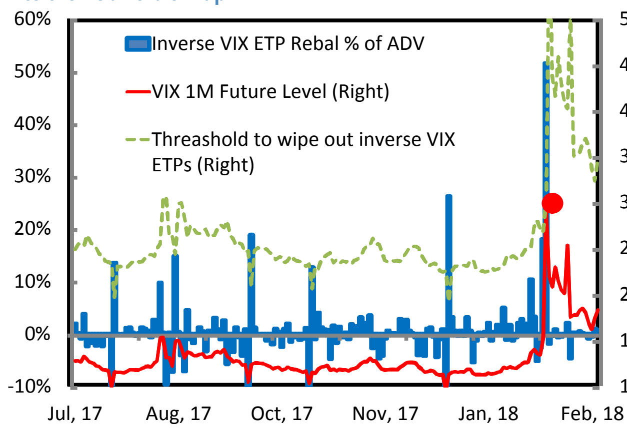
We have extensively documented the impact of index option hedging flows in our previous research (see here, here). We also closely follow the speculative activity around these flows. At the onset of volatility, these flows can significantly impact the market near the close. It takes a few days before speculators establish the positioning and hedging patterns and start anticipating these flows (see here).

Another systematic strategy with predictable flows is levered and inverse exchange traded products – similar to index options hedging, these products are short gamma (note that levered/inverse ETF gamma is typically much smaller than index option gamma). Given that levered and inverse ETFs are short gamma, their rebalancing results in systematic flows that can be anticipated by speculators, which negatively affects the performance of these products (see here and here). A recent example is the demise of the inverse volatility product XIV. When volatility increased in February, the size of rebalance could not be digested by the market. Liquidity

Marko Kolanovic, PhD
(1-212) 272-1438
marko.kolanovic@jpmorgan.com

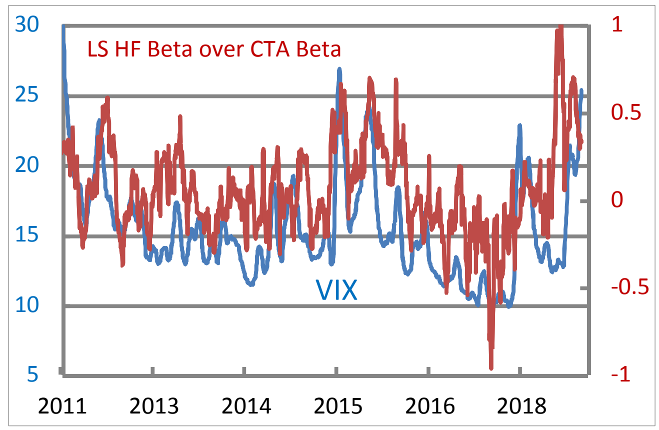
providers, with knowledge of large rebalance flows, were not eager to step in until the product self-destructed. Figure 5 shows rebalance flow as % of average daily VIX volume as well as the level of the VIX at which product 'self-destructed.' As soon as the VIX "tagged" this level, volatility quickly subsided.

Figure 5: Rebalance flow for inverse VIX ETPs, as a % of 3M ADV, into the Feb'18 blow-up



Source: J.P. Morgan QDS.

Figure 6: Difference between the beta of long-short HFs and CTAs to the VIX



Source: J.P. Morgan QDS, HFR.

Trend following and volatility targeting strategies are also typically short gamma. Volatility targeting can be applied to any portfolio (e.g., 60/40, risk parity, factor portfolio, a platform of fundamental PMs, etc.). Volatility targeting is explicitly short gamma in a mean-reverting market. The strategy reduces risk when volatility is rising and increases risk when volatility is falling. This is by design (risk exposure ~1/volatility), and in that way flows from these strategies are closely related to option hedging. Note that we estimate the notional amount of these strategies at ~$300bn in mutli-asset portfolios, which is much smaller than the delta weighted put open interest in Q4 of ~$750bn notional just for the S&P 500 index. In addition, these strategies sell over several days (unlike option hedges that sell within a day). CTAs' short gamma exposure is not explicit, but still intuitive as they sell when an asset price declines, and buy when it goes up (additionally, many CTA strategies volatility target). Of course, not only systematic investors sell into VIX spikes. Equity long-short hedge funds also sell into VIX spikes, but perhaps less programmatically and aggressively. An indication for this is the sensitivity of funds' beta to the VIX. For instance, CTAs' beta to the VIX is about ~4 times higher than equity long short HFs' beta to the VIX (e.g., -3.5% vs -0.9%). Figure 6 shows the difference between the beta of equity long-short HFs and CTAs and the VIX. When the VIX increases, CTAs are quicker in reducing beta (selling stocks) than equity long-short hedge funds.

The analysis above by no means passes judgment on the merits of various short gamma systematic strategies that are often used for hedging or risk control. We do note that these strategies require adjustments due to the changing market environment (e.g., liquidity-flow-volatility feedback loop, speculative flows, etc.). If systematic flows are significant enough to impact the market, they will impact their own performance via speculative flows and market impact.

Which strategies may be impacted – some simple checks would include:

- Strategies where the asset base and flows are large relative to market liquidity (i.e., crowding).

- Strategies where the flows are correlated to volatility. The reason for this is the volatility-liquidity-flow feedback loop, which makes the effective asset size 'appear larger' than it is. Strategies that are inherently short gamma are affected more.
- Strategies that are entirely transparent and don't adjust along the way (e.g., if a strategy is documented in a prospectus or academic whitepaper, it will more likely invite 'copycats' or speculative flows).
- In addition to the above, poor performance of a strategy may indicate crowding or damage from speculative flows or short gamma exposure.

QE/QT and Liquidity

Given the recent collapse in liquidity and the feedback loop of flows-liquidity-volatility, investors are very attentive to monetary policy measures that may affect liquidity. The most closely watched metric is the pace of the Fed's balance sheet reduction. For instance, a recent example is the negative market reaction on the comment that balance sheet reduction (QT) will be on autopilot (and positive reaction when this statement was later modified). Even passing remarks on the balance sheet can have visible and significantly negative intraday impacts on markets (e.g., recent remarks that the balance sheet should be substantially smaller).

Why is there such a focus on the Fed's balance sheet from investors? Adding liquidity in the form of QE had a positive impact on asset classes over the past decade. We estimated the impact of QE to be ~20% of equity prices based on causality tests (see our report here). The questions investors struggle with are how negative was/will be the impact of the QT. It is plausible that dollar for dollar, QT has a significantly larger impact than QE. The reason for that may be the above-explained fragility feedback loop. During QE, both central banks and investors more broadly buy assets in an environment of low volatility/increased liquidity when the impact is small, and during QT assets are typically sold while liquidity is removed, compounding the negative impact of other outflows.

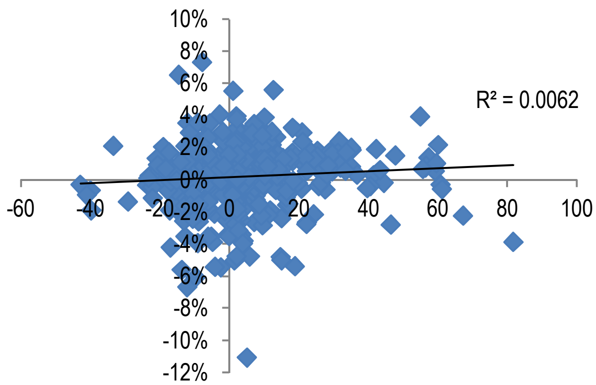
To our knowledge, there is no broadly accepted understanding of the exact mechanics and magnitude of QT's impact (e.g., how much it is a signal to the market, vs. mechanical supply/demand and price impact). There is a significant relationship between the Fed's balance sheet changes and the market, but the big drivers of this relationship are points when the large QE programs were announced such as March 2009 (e.g., when this point is taken out, the relationship no longer appears statistically significant; Figure 7 shows the weak contemporaneous relationship since the start of 2010). Whatever the real mechanical impact is, likely the impact on market sentiment is much larger (i.e., self-fulfilling impact). In support of that are recent intraday movements on balance sheet mentions, as well as the price action of the S&P 500 during Q4 shown in Figure 8. While there may be little or no mechanical impact on equity prices, most macro traders are not 'fighting the Fed' – when liquidity is added they are buying assets, and when liquidity is removed they are selling assets. Over the past months, we have heard a large number of anecdotes where investors avoid buying risky assets during (or actively sell into) weeks when there is a significant balance sheet reduction (e.g., traders taping the schedule to their screens, blogs and email chains, etc.).

In this way, balance sheet reductions put significant strain on market sentiment, on flows and on the weakest link in the market – the liquidity-volatility-flow feedback loop. If the balance sheet reduction is a signal to sell, volatility increases, liquidity

Marko Kolanovic, PhD
(1-212) 272-1438
marko.kolanovic@jpmorgan.com

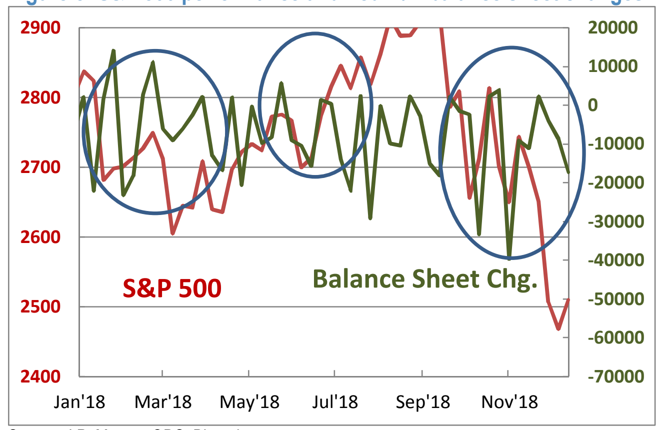
decreases, and additional systematic flows are triggered. Balance sheet driven market fragility is thus increasing the risk of market disruptions and ultimately the risk of a recession – which is in contrast to policy makers' intentions.

Figure 7: Fed weekly balance sheet change (x-axis, $Bn) vs. S&P 500 returns (y-axis) was not statistically significant (since 2010)



Source: J.P. Morgan QDS, Bloomberg.

Figure 8: S&P 500 performance and Fed w/w balance sheet changes



Source: J.P. Morgan QDS, Bloomberg.

Marko Kolanovic, PhD
(1-212) 272-1438
marko.kolanovic@jpmorgan.com

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.

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 his or her 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, 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.

Important Disclosures

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 January 02, 2019

	Overweight (buy)	Neutral (hold)	Underweight (sell)
J.P. Morgan Global Equity Research Coverage	46%	40%	14%
IB clients*	53%	47%	37%
JPMS Equity Research Coverage	44%	41%	15%
IB clients*	75%	65%	56%

*Percentage of investment banking clients in each rating category.
For purposes only of FINRA/NYSE 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.

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.

Equity Analysts' Compensation: The equity 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.

Other Disclosures

J.P. Morgan ("JPM") is the global brand name for J.P. Morgan Securities LLC ("JPMS") and its affiliates worldwide. J.P. Morgan Cazenove is a marketing name for the U.K. investment banking businesses and EMEA cash equities and equity research businesses of JPMorgan Chase & Co. and its subsidiaries.

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.

Options related research: If the information contained herein regards options related research, such information is available only to persons who have received the proper option risk disclosure documents. For a copy of the Option Clearing Corporation's Characteristics and Risks of Standardized Options, please contact your J.P. Morgan Representative or visit the OCC's website at https://www.theocc.com/components/docs/riskstoc.pdf

Private Bank Clients: Where you are a client of the private banking businesses offered by JPMorgan Chase & Co. and its subsidiaries (“J.P. Morgan Private Bank”), research is issued 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 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. **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 (SEBI Registration Number - INB 230675231/INF 230675231/INE 230675231), the Bombay Stock Exchange Limited (SEBI Registration Number - INB 010675237/INF 010675237) 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) 099/04/2018 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) 046/09/2018], 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. **Saudi Arabia**: J.P. Morgan Saudi Arabia Ltd. is authorized by the Capital Market Authority of the Kingdom of Saudi Arabia (CMA) to carry out dealing as an agent, arranging, advising and custody, with respect to securities business under licence number 35-07079 and its registered address is at 8th Floor, Al-Faisaliyah Tower, King Fahad Road, P.O. Box 51907, Riyadh 11553, Kingdom of Saudi Arabia. **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.

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. **Hong Kong:** The 1% ownership disclosure as of the previous month end satisfies the requirements under Paragraph 16.5(a) of the Hong Kong Code of Conduct for Persons Licensed by or Registered with the Securities and Futures Commission. (For research published within the first ten days of the month, the disclosure may be based on the month end data from two months prior.) J.P. Morgan Broking (Hong Kong) Limited is the liquidity provider/market maker for derivative warrants, callable bull bear contracts and stock options listed on the Stock Exchange of Hong Kong Limited. An updated list can be found on HKEx website: http://www.hkex.com.hk. **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 persons whose principal business is the investment of money or who, in the course of and for the purposes of their business, habitually invest money. JPMSAL does not issue or distribute this material to members of "the public" as determined in accordance with section 3 of the Securities Act 1978. 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:** The information contained herein is not, and under no circumstances is to be construed as, a prospectus, an advertisement, a public offering, 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. Any offer or sale of the securities described herein in Canada will be made only under an exemption from the requirements to file a prospectus with the relevant Canadian securities regulators and only by a dealer properly registered under applicable securities laws or, alternatively, pursuant to an exemption from the dealer registration requirement in the relevant province or territory of Canada in which such offer or sale is made. 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. To the extent that the information contained herein references securities of an issuer incorporated, formed or created under the laws of Canada or a province or territory of Canada, any trades in such securities must be conducted through a dealer registered in Canada. No securities commission or similar regulatory authority in Canada has reviewed or in any way passed judgment upon these materials, the information contained herein or the merits of the securities described herein, and any representation to the contrary is an offence. **Dubai:** This report has been issued to persons regarded as professional clients 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 January 01, 2019.

Marko Kolanovic, PhD
(1-212) 272-1438
marko.kolanovic@jpmorgan.com