UBS

Global Research

March 2018

Risk Modelling with Style

UBS Quantitative Conference 2018

David Jessop
Analyst
Tel: +44 20 7567 9882
david.jessop@ubs.com

Claire Jones, CFA
Analyst
Tel: +44 20 7568 1873
claire-c.jones@ubs.com

Desi Ivanova
Analyst
Tel: +44 20 7568 1754
desi-r.ivanova@ubs.com

Josie Gerken, PhD
Analyst
Tel: +44 20 7568 3560
josephine.gerken@ubs.com

This document has been prepared by UBS Limited

Outline of Talk[1]

1. Taxonomy of Risk Models - Statistical, Time Series, Cross-Section
2. Pros and Cons of approaches and with particular attention to robustness to data and specification error.
   - Cross-sectional models robust except to measurement error in factor loadings
3. Errors-in-variable problem in cross-sectional risk models
4. A solution: instrument using estimates of lagged style betas
5. Show that there is significant bias, that instrument can reduce this bias, and particularly strong for some styles.
   - Discuss results in light of debate on stock characteristics versus risk loadings.

[1]The authors would like to thank Professor James Sefton of Imperial College, London for the significant contribution he provided to this material.

UBS

Taxonomy of Risk Models

- Returns are assumed to generated by the LFM

$$r_t = Bf_t + \varepsilon_t$$
$$Cov(f_t) = \Omega \text{ and } Cov(\varepsilon_t) = \mathrm{D}$$

Diagonal

- The Risk Matrix $\mathbf{V} = \mathbf{B\Omega B}' + \mathbf{D}$ can be estimated using a
  - Statistical Approach: estimated conditional on knowing the number of factors, *k*
  - Time Series Approach: estimated conditional on knowing the factor returns, $\mathbf{F}$
  - Cross-Sectional Approach: estimated conditional on knowing the factor loadings, $\mathbf{B}$

- Hybrid Models first estimate the structural component, conditional on knowing some of the factor returns, $\mathbf{F}$, or some of the factor loadings, $\mathbf{B}$, and then estimate the other ‘blind’ factors using a statistical approach

UBS

The Trade-Offs

- The central trade-off in risk model design is between:

  Structural Error vs Estimation Error

- The more structure that is imposed on the model then:
  - the fewer parameters that will need to be estimated, so the smaller the estimation error.
  - But the more likely you have mis-specified the model so the greater the structural error.

Pros and Cons

- Assume N (=500) stocks, T (=156) periods and K (=30) Factors

	Parameters to Estimate	Example	Pros	Cons
Statistical	$NK + \frac{K(K+1)}{2} + N$	15,965	Imposes no Structure $\Rightarrow$ No estimation bias $\Rightarrow$ Picks up transitory factors	High estimation error (especially if transitory) No risk or return attribution
Time-Series	$NK + N$	15,500	Clear Risk attribution (orthogonalise factors) Estimated coefficients unbiased	Hard to include dynamic factors (e.g short-term momentum) Harder to do return attribution
Cross-Sectional	$\frac{K(K+1)}{2} + N$	965	Good for return attribution Can incorporate 'new' stocks Factor exposures can be dynamic	Estimated coefficients biased $\Rightarrow$Tends to need greater number of factors

UBS

Understanding Factor Models (Episode1)

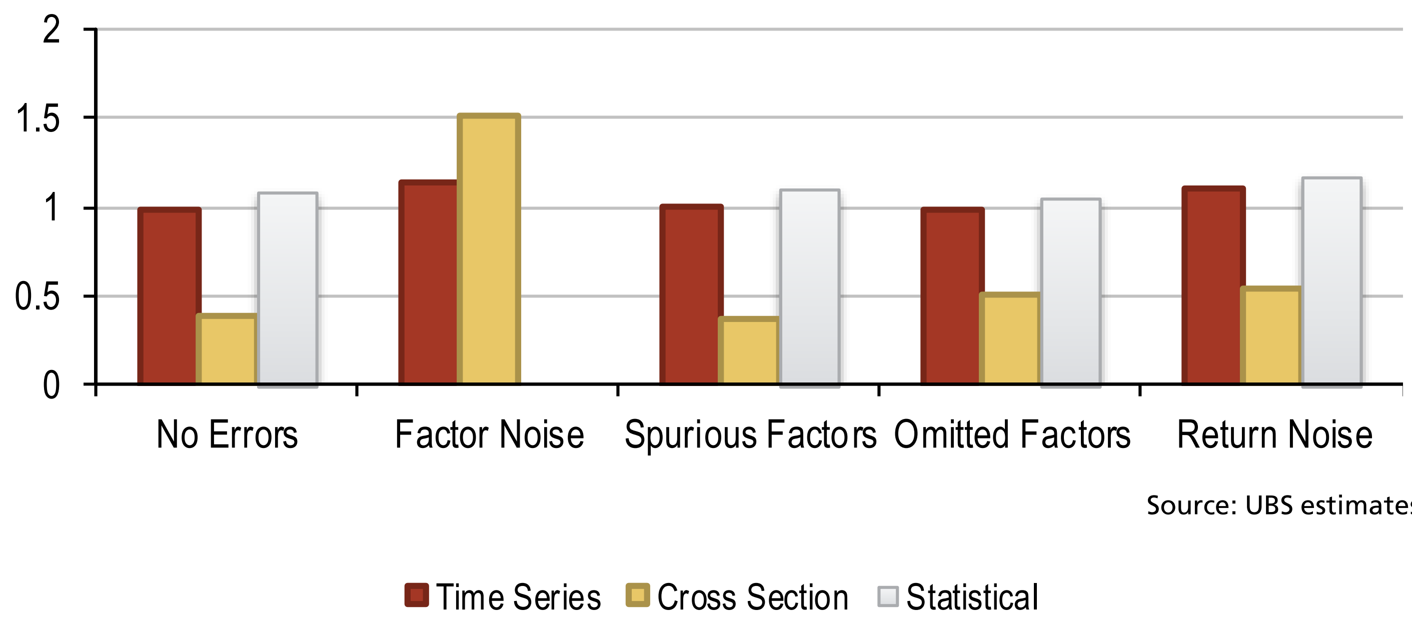
- We assume the 'true' LFM model is the PAS risk model estimated on monthly returns to S&P 500 stocks over the last 5 years
  - The results *will* depend on the general structure of the 'true' model - we therefore used as our 'true' model one that was generated from historical data
- We estimate a risk matrix using the three modelling approaches on each of 1000 synthetic return histories generated from the 'true' model
  - assuming **no error** in the prior information (focusing on sampling errors only)
  - after adding 2 **spurious factors** to either **F** or **B** or incrementing K by 2
  - after **omitting 2 Factors** factor from either **F** and **B** or reducing K by 2.
  - after adding **factor noise** to the prior information: zero mean Gaussian noise with sd of half actual factor volatility is added to **F** - to the market and style betas in **B** we add zero mean Gaussian noise with volatility of 0.25; we round the sector and country betas in **B** to either 1 or 0
  - after adding **return noise** to **R** with a standard deviation of 0.1
- We measure the cost of the estimation errors as the average
  - increase in tracking error of the best 50 stock index tracker
  - increase in variance of the minimum variance portfolio

  calculated from the estimated risk matrix relative to that calculated from the 'true' one

Tracking Errors - the cost of not using the true model

	Time Series	Cross Section	Statistical
No Errors	0.99	0.38	1.08
Factor Noise	1.14	**1.52**	
Spurious Factors	1.01	0.37	1.10
Omitted Factors	0.98	0.50	1.06
Return Noise	1.11	0.54	1.17

Source: UBS estimates



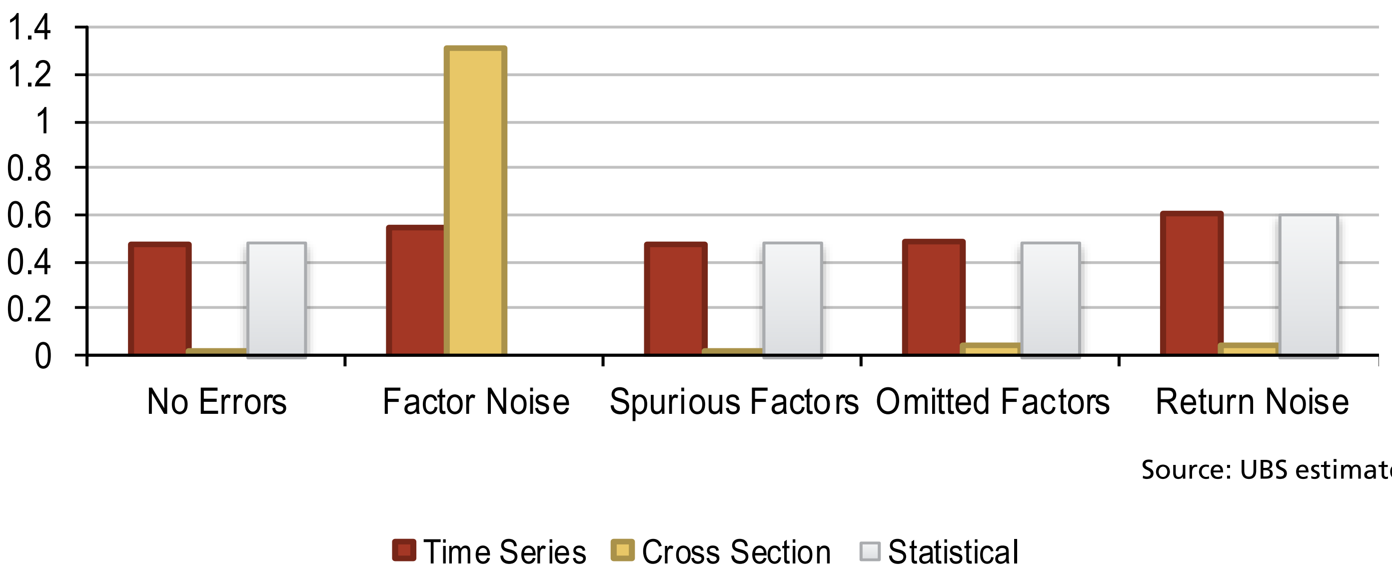
Source: UBS estimates

UBS

Minimum Variance- cost of not using the true risk model

	Time Series	Cross Section	Statistical
No Errors	0.48	0.02	0.49
Factor Noise	0.55	**1.31**	
Spurious Factors	0.48	0.02	0.49
Omitted Factors	0.49	0.04	0.49
Return Noise	0.61	0.04	0.61

Source: UBS estimates



Source: UBS estimates

UBS

Bias in Cross-Sectional Risk Models
Errors in Variables

- In a cross-section regression (CSR), we regress the factor loadings, B, on excess returns, r_t to estimate factor returns, f_t

$$r = Bf + \varepsilon_t$$

- However we do not observe risk loadings , B, – in particular when we think about style – we observe style characteristics, $\widehat{B}$,
  - For example we use Book/Price ratio as proxy for loading on value factor – see discussion Kent and Titman (1997), Davis, Fama, French (2000), Chordia, Goyal, Shanken (2015).

$$\widehat{B} = B + V_t$$

- Substituting in implies

$$r = \widehat{B}f - (\varepsilon_t - V_t f)$$

and so the equation residual $(\varepsilon_t - V_t f)$ is correlated with regressors $\widehat{B}$

UBS

Bias in Cross-Sectional Risk Models
Errors in Variables

- The OLS estimate is

$$\hat{f} = \left(\hat{B}^T\hat{B}\right)^{-1}\hat{B}^T r = f + \left(\hat{B}^T\hat{B}\right)^{-1}\hat{B}^T(\varepsilon_t - V_t f)$$

- Is therefore biased

$$E\hat{f} = \left(\hat{B}^T\hat{B}\right)^{-1}\hat{B}^T r = f - \underbrace{\left(\hat{B}^T\hat{B}\right)^{-1}E\left({V_t}^T V_t\right)}_{\neq 0}f$$

- and this bias can be significant and will attenuate estimates

UBS

History of Problem
A few milestones

- Long history ever since first Fama-MacBeth (1973) regressions. In this seminal paper, Fama-MacBeth suggest using portfolios rather than single securities to minimise the EIV problem. Blume (1975) offers a similar suggestion.
- Shanken (1992) derives adjusted standard errors for the two-pass estimator
- Kim (1995) suggested that standard errors in the first pass regression could be used to adjust for the bias in the CSR.
- Ang, Liu and Schwartz (2017) demonstrate that these error bounds are tighter using individual securities rather than portfolios.

- Standard approach to errors-in-variables problems is to use instruments.
- Jegadeesh, Noh, Roll *et al. (2016)* suggest using betas estimated from obs. at t-1, t-4, t-7 … as instruments for CSR on returns at t, t-3, t-6 … using betas estimated from obs t-2, t-5, t-7 …
- Here we use lagged betas to instrument our CSR of characteristics on returns.

UBS

Instrumental Variables
A solution to EIV problems

- Instrumental variables has a long history too! The idea is to find instruments, that are correlated with the regressors but not with the errors.
- We propose to use the lagged historical betas as instruments to the security style characteristics. Denote these lagged beta instruments as Z.
- Our CSR is

$$r = \hat{B}f - (\varepsilon_t - V_t f)$$

- Multiply on left by $\left(Z^T\hat{B}\right)^{-1}Z^T$

$$\hat{f} = \left(Z^T\hat{B}\right)^{-1}Z^T r = f + \left(Z^T\hat{B}\right)^{-1}Z^T(\varepsilon_t - V_t f)$$

- But now instruments uncorrelated with ε_t and so take expectations

$$E(\hat{f}) = \left(Z^T\hat{B}\right)^{-1}Z^T r = f + \underbrace{\left(Z^T\hat{B}\right)^{-1}Z^T(\varepsilon_t - V_t f)}_{\textbf{Expected value = 0}}$$

UBS

Instrumental Variables
Are the instruments valid?

- There are some things we need to think about

1. **Weak Instruments**: the instruments need to be sufficiently correlated with the regressors. This is an F-test of the null that all coefficients are zero in a regression of the instruments on the regressors.

2. **Is there evidence of bias (Hausman-Wu test):** Estimate factor returns *f* using OLS and then using instrument variables and test if the two estimates are significantly different.

3. **Are the instruments uncorrelated with the residual returns (Sargan overidentication test):** Test the covariance between instruments and estimated residuals is significantly different from zero; test requires more instruments that regressors
   – If no. of regressors equals no. of instruments, covariance will be identically zero (optimality condition).

UBS

Understanding Factor Models (Episode 2)

- Cross-sectional Risk Model estimated for MSCI Europe Large and Mid Cap Universe
  - Roughly 450 -500 stocks
  - Factors returns estimated for week over last 3 years (156 obs)

- Loadings, *B* used to estimate factor returns
  1. Market factor - estimated market beta on 3 year returns before end of previous month
  2. 11 GICs Sector Factors - loading of 1 indicates sector membership, 0 otherwise.
  3. 8 country regions – loading of 1 indicates region membership, 0 otherwise.
     (GB/IR,BG/NL/LX, FR, GE/AUT, SP/PT, IT/GR, SWE/DK/NOR/FIN, SW)
  4. 9 Style Factors - Use cross-sectional scores normalised by sector to have zero mean and unit std dev. Styles: Market Cap, 12m Volatility, 1m momentum, 6m momentum, Earnings Yield, Free Cash Flow Yield, 3m Earnings Momentum, ROE, Net Debt to EV

  (To avoid co-linearity, impose that sum of sector factor returns and sum region factors returns equal 0)

- Instrumental Variables
  1. Use market betas, sector and region indicators (so these are not instrumented).
  2. Instrument styles using beta estimated by regressing stock returns on respective UBS long short style index returns using 6 month returns up to beginning of previous month

UBS

Strength of Instruments

- Instruments checked for strength.
  - Regress loadings (normalised scores) on instruments (lagged betas). Test null that all coefficients are zero.
- Count in how many periods the instruments are strong enough ($p<0.01$)

	Mkt. Cap.	12m Vol.	6m Mom.	1m Mom.	Earn. Yield	FCF Yield	3m Earn. Mom	ROE	Net Debt / EV
Jun-17	**156**	**156**	**117**	16	**147**	47	**104**	**122**	28
Jun-16	**156**	**156**	**117**	12	**138**	9	**135**	**104**	57
Jun-15	**156**	**156**	99	19	**143**	14	**131**	**101**	**114**
Jun-14	**156**	**156**	89	17	**147**	65	**135**	**108**	**150**
Jun-13	**156**	**156**	86	17	**156**	78	95	81	**148**
Jun-12	**156**	**156**	89	17	**138**	41	51	73	**113**

Source: UBS estimates

Evidence of significant bias

- Use Hausman-Wu test of whether OLS estimates are significantly different from instrumented estimates

	$p<0.01$	$0.01<p<0.05$	$0.05<p<0.1$	$0.1<p<0.2$	$p>=0.2$
Jun-17	78	38	17	19	4
Jun-16	60	27	27	16	26
Jun-15	73	35	17	23	8
Jun-14	84	38	21	10	3
Jun-13	72	40	20	21	3
Jun-12	59	38	16	11	32

Source: UBS estimates

Are instruments uncorrelated

- If style score is weakly correlated with instruments, include that score as additional instrument and test whether other instruments are uncorrelated with errors (Sargan overidentification test)

	p<0.01	0.01<p<0.05	0.05<p<0.1	0.1<p<0.2	p>=0.2
Jun-17	16	16	13	16	95
Jun-16	11	18	9	15	103
Jun-15	11	17	11	19	98
Jun-14	10	11	10	11	114
Jun-13	9	11	13	27	96
Jun-12	8	12	16	23	97

Source: UBS estimates

An estimate of the size of the bias

- Estimate factor correlation matrix $\widehat{\Omega} = \frac{1}{T=156} \sum_t f_t f_t{}^T$ using instrument and OLS approaches.
- Look at ratio of the estimated factor standard deviations.

	Mkt. Cap.	12m Vol.	6m Mom.	1m Mom.	Earn. Yield	FCF Yield	3m Earn. Mom	ROE	Net Debt / EV
Jun-17	**1.9**	1.4	1.1	1.0	**2.1**	**1.8**	**2.1**	**2.5**	1.4
Jun-16	**1.8**	1.6	1.2	1.0	**1.9**	1.3	**2.5**	**2.4**	**1.8**
Jun-15	**1.7**	1.5	1.2	1.1	**1.9**	1.6	**2.3**	**3.6**	**2.4**
Jun-14	**1.8**	1.3	1.0	1.2	1.6	**1.7**	**2.5**	**3.5**	**2.7**
Jun-13	**1.9**	1.2	1.0	1.1	**1.9**	1.6	**2.3**	**2.5**	**1.9**
Jun-12	**1.7**	1.3	0.9	1.1	**1.8**	1.5	**1.8**	**1.8**	**1.9**

Source: UBS estimates

UBS

Conclusions

- The errors-in-variable problem in cross-section model estimation can account for the weak contribution of style to risk to overall portfolio risk.
- A possible solution is to instrument the style scores in the regressions using lagged style betas.
  - Evidence that these are strong instruments
  - Evidence that they are also uncorrelated with residual returns

- Tests on risk models for Europe suggest that the problem is particularly acute for size (market cap) and quality styles.
- This links closely to the debate between stock characteristics and stock risk betas.

UBS

References

- Ang, Andrew, Jun Liu, and Krista Schwarz. *Using stocks or portfolios in tests of asset pricing models*. Working paper, Columbia University, 2017.
- Blume, Marshall E. "Betas and their regression tendencies." *The Journal of Finance* 30, no. 3 (1975): 785-795.
- Chordia, Tarun, Amit Goyal, and Jay Shanken. "Cross-sectional asset pricing with individual stocks: betas versus characteristics." (2015).
- Daniel, Kent, and Sheridan Titman. "Evidence on the characteristics of cross sectional variation in stock returns." *the Journal of Finance* 52, no. 1 (1997): 1-33.
- Davis, James L., Eugene F. Fama, and Kenneth R. French. "Characteristics, covariances, and average returns: 1929 to 1997." *The Journal of Finance* 55, no. 1 (2000): 389-406.
- Fama, Eugene F., and James D. MacBeth. "Risk, return, and equilibrium: Empirical tests." *Journal of political economy* 81, no. 3 (1973): 607-636.
- Jegadeesh, Narasimhan, Joonki Noh, Kuntara Pukthuanthong, Richard Roll, and Junbo L. Wang. "Empirical tests of asset pricing models with individual assets: Resolving the errors-in-variables bias in risk premium estimation." (2016).
- Kim, D., 1995, "The Errors in the variables problem in the cross-section of expected stock returns." Journal of Finance, 50, 1605-1634.
- Shanken, Jay. "On the estimation of beta-pricing models." *The review of financial studies* 5, no. 1 (1992): 1-33.

Valuation Method and Risk Statement

Our quantitative models rely on reported financial statement information, consensus earnings forecasts and stock prices. Errors in these numbers are sometimes impossible to prevent (as when an item is misstated by a company). Also, the models employ historical data to estimate the efficacy of stock selection strategies and the relationships among strategies, which may change in the future. Additionally, unusual company-specific events could overwhelm the systematic influence of the strategies used to rank and score stocks.

Analyst Certification

Each research analyst primarily responsible for the content of this research report, in whole or in part, certifies that with respect to each security or issuer that the analyst covered in this report: (1) all of the views expressed accurately reflect his or her personal views about those securities or issuers and were prepared in an independent manner, including with respect to UBS, and (2) no part of his or her compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views expressed by that research analyst in the research report.

Required Disclosures

This document has been prepared by UBS Limited, an affiliate of UBS AG. UBS AG, its subsidiaries, branches and affiliates are referred to herein as UBS.

For information on the ways in which UBS manages conflicts and maintains independence of its research product; historical performance information; and certain additional disclosures concerning UBS research recommendations, please visit www.ubs.com/disclosures. The figures contained in performance charts refer to the past; past performance is not a reliable indicator of future results. Additional information will be made available upon request. UBS Securities Co. Limited is licensed to conduct securities investment consultancy businesses by the China Securities Regulatory Commission. UBS acts or may act as principal in the debt securities (or in related derivatives) that may be the subject of this report. This recommendation was finalized on 13 March 2018, 03:53 AM GMT. UBS has designated certain Research department members as Derivatives Research Analysts where those department members publish research principally on the analysis of the price or market for a derivative, and provide information reasonably sufficient upon which to base a decision to enter into a derivatives transaction. Where Derivatives Research Analysts co-author research reports with Equity Research Analysts or Economists, the Derivatives Research Analyst is responsible for the derivatives investment views, forecasts, and/or recommendations.

Required Disclosures (continued)

UBS Investment Research: Global Equity Rating Definitions

12-Month Rating	Definition	Coverage[1]	IB Services[2]
Buy	FSR is > 6% above the MRA.	46%	27%
Neutral	FSR is between -6% and 6% of the MRA.	39%	24%
Sell	FSR is > 6% below the MRA.	16%	13%
Short-Term Rating	**Definition**	**Coverage[3]**	**IB Services[4]**
Buy	Stock price expected to rise within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%
Sell	Stock price expected to fall within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%

Source: UBS. Rating allocations are as of 31 December 2017.
1:Percentage of companies under coverage globally within the 12-month rating category.
2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months.
3:Percentage of companies under coverage globally within the Short-Term rating category.
4:Percentage of companies within the Short-Term rating category for which investment banking (IB) services were provided within the past 12 months.

KEY DEFINITIONS:Forecast Stock Return (FSR) is defined as expected percentage price appreciation plus gross dividend yield over the next 12 months. **Market Return Assumption (MRA)** is defined as the one-year local market interest rate plus 5% (a proxy for, and not a forecast of, the equity risk premium). **Under Review (UR)** Stocks may be flagged as UR by the analyst, indicating that the stock's price target and/or rating are subject to possible change in the near term, usually in response to an event that may affect the investment case or valuation. **Short-Term Ratings** reflect the expected near-term (up to three months) performance of the stock and do not reflect any change in the fundamental view or investment case. **Equity Price Targets** have an investment horizon of 12 months.

EXCEPTIONS AND SPECIAL CASES:UK and European Investment Fund ratings and definitions are: Buy: Positive on factors such as structure, management, performance record, discount; **Neutral:** Neutral on factors such as structure, management, performance record, discount; **Sell:** Negative on factors such as structure, management, performance record, discount. **Core Banding Exceptions (CBE):** Exceptions to the standard +/-6% bands may be granted by the Investment Review Committee (IRC). Factors considered by the IRC include the stock's volatility and the credit spread of the respective company's debt. As a result, stocks deemed to be very high or low risk may be subject to higher or lower bands as they relate to the rating. When such exceptions apply, they will be identified in the Company Disclosures table in the relevant research piece.

Research analysts contributing to this report who are employed by any non-US affiliate of UBS Securities LLC are not registered/qualified as research analysts with FINRA. Such analysts may not be associated persons of UBS Securities LLC and therefore are not subject to the FINRA restrictions on communications with a subject company, public appearances, and trading securities held by a research analyst account. The name of each affiliate and analyst employed by that affiliate contributing to this report, if any, follows.

UBS Limited: David Jessop, Claire Jones, Desi Ivanova, Josie Gerken

Unless otherwise indicated, please refer to the Valuation and Risk sections within the body of this report. For a complete set of disclosure statements associated with the companies discussed in this report, including information on valuation and risk, please contact UBS Securities LLC, 1285 Avenue of Americas, New York, NY 10019, USA, Attention: Investment Research.

Compendium Disclosure

For a complete set of disclosure statements associated with the companies discussed in this report, including information on valuation and risk, please contact:

UBS Securities LLC,
1285 Avenue of Americas,
New York, NY 10019, USA.

Attention: Publishing Administration

Global Disclaimer

This document has been prepared by UBS Limited, an affiliate of UBS AG. UBS AG, its subsidiaries, branches and affiliates are referred to herein as UBS.

Global Research is provided to our clients through UBS Neo, in certain instances, UBS.com and any other system, or distribution method specifically identified in one or more communications distributed through UBS Neo or UBS.com as an approved means for distributing Global Research (each a "System"). It may also be made available through third party vendors and distributed by UBS and/or third parties via e-mail or alternative electronic means. The level and types of services provided by Global Research to a client may vary depending upon various factors such as a client's individual preferences as to the frequency and manner of receiving communications, a client's risk profile and investment focus and perspective (e.g., market wide, sector specific, long-term, short-term, etc.), the size and scope of the overall client relationship with UBS and legal and regulatory constraints.

All Global Research is available on UBS Neo. Please contact your UBS sales representative if you wish to discuss your access to UBS Neo.

When you receive Global Research through a System, your access and/or use of such Global Research is subject to this Global Research Disclaimer and to the terms of use governing the applicable System.

When you receive Global Research via a third party vendor, e-mail or other electronic means, you agree that use shall be subject to this Global Research Disclaimer, where applicable the UBS Investment Bank terms of business (https://www.ubs.com/global/en/investment-bank/regulatory.html) and to UBS's Terms of Use/Disclaimer (http://www.ubs.com/global/en/legalinfo2/disclaimer.html). In addition, you consent to UBS processing your personal data and using cookies in accordance with our Privacy Statement (http://www.ubs.com/global/en/legalinfo2/privacy.html) and cookie notice (http://www.ubs.com/global/en/homepage/cookies/cookie-management.html).

If you receive Global Research, whether through a System or by any other means, you agree that you shall not copy, revise, amend, create a derivative work, provide to any third party, or in any way commercially exploit any UBS research provided via Global Research or otherwise, and that you shall not extract data from any research or estimates provided to you via Global Research or otherwise, without the prior written consent of UBS.

This document is for distribution only as may be permitted by law. It is not directed to, or intended for distribution to or use by, any person or entity who is a citizen or resident of or located in any locality, state, country or other jurisdiction where such distribution, publication, availability or use would be contrary to law or regulation or would subject UBS to any registration or licensing requirement within such jurisdiction.

This document is a general communication and is educational in nature; it is not an advertisement nor is it a solicitation or an offer to buy or sell any financial instruments or to participate in any particular trading strategy. Nothing in this document constitutes a representation that any investment strategy or recommendation is suitable or appropriate to an investor’s individual circumstances or otherwise constitutes a personal recommendation. By providing this document, none of UBS or its representatives has any responsibility or authority to provide or have provided investment advice in a fiduciary capacity or otherwise. Investments involve risks, and investors should exercise prudence and their own judgment in making their investment decisions. None of UBS or its representatives is suggesting that the recipient or any other person take a specific course of action or any action at all. By receiving this document, the recipient acknowledges and agrees with the intended purpose described above and further disclaims any expectation or belief that the information constitutes investment advice to the recipient or otherwise purports to meet the investment objectives of the recipient. The financial instruments described in the document may not be eligible for sale in all jurisdictions or to certain categories of investors. Options, derivative products and futures are not suitable for all investors, and trading in these instruments is considered risky. Mortgage and asset-backed securities may involve a high degree of risk and may be highly volatile in response to fluctuations in interest rates or other market conditions. Foreign currency rates of exchange may adversely affect the value, price or income of any security or related instrument referred to in the document. For investment advice, trade execution or other enquiries, clients should contact their local sales representative.

The value of any investment or income may go down as well as up, and investors may not get back the full (or any) amount invested. Past performance is not necessarily a guide to future performance. Neither UBS nor any of its directors, employees or agents accepts any liability for any loss (including investment loss) or damage arising out of the use of all or any of the Information.

Prior to making any investment or financial decisions, any recipient of this document or the information should seek individualized advice from his or her personal financial, legal, tax and other professional advisors that takes into account all the particular facts and circumstances of his or her investment objectives.

Any prices stated in this document are for information purposes only and do not represent valuations for individual securities or other financial instruments. There is no representation that any transaction can or could have been effected at those prices, and any prices do not necessarily reflect UBS's internal books and records or theoretical model-based valuations and may be based on certain assumptions. Different assumptions by UBS or any other source may yield substantially different results.

No representation or warranty, either expressed or implied, is provided in relation to the accuracy, completeness or reliability of the information contained in any materials to which this document relates (the "Information"), except with respect to Information concerning UBS. The Information is not intended to be a complete statement or summary of the securities, markets or developments referred to in the document. UBS does not undertake to update or keep current the Information. Any opinions expressed in this document may change without notice and may differ or be contrary to opinions expressed by other business areas or groups, personnel or other representative of UBS. Any statements contained in this report attributed to a third party represent UBS's interpretation of the data, information and/or opinions provided by that third party either publicly or through a subscription service, and such use and interpretation have not been reviewed by the third party. In no circumstances may this document or any of the Information (including any forecast, value, index or other calculated amount ("Values")) be used for any of the following purposes:

(i) valuation or accounting purposes;

(ii) to determine the amounts due or payable, the price or the value of any financial instrument or financial contract; or

(iii) to measure the performance of any financial instrument including, without limitation, for the purpose of tracking the return or performance of any Value or of defining the asset allocation of portfolio or of computing performance fees.

By receiving this document and the Information you will be deemed to represent and warrant to UBS that you will not use this document or any of the Information for any of the above purposes or otherwise rely upon this document or any of the Information.

UBS has policies and procedures, which include, without limitation, independence policies and permanent information barriers, that are intended, and upon which UBS relies, to manage potential conflicts of interest and control the flow of information within divisions of UBS and among its subsidiaries, branches and affiliates. For further information on the ways in which UBS manages conflicts and maintains independence of its research products, historical performance information and certain additional disclosures concerning UBS research recommendations, please visit www.ubs.com/disclosures.

Research will initiate, update and cease coverage solely at the discretion of UBS Research Management, which will also have sole discretion on the timing and frequency of any published research product. The analysis contained in this document is based on numerous assumptions. All material information in relation to published research reports, such as valuation methodology, risk statements, underlying assumptions (including sensitivity analysis of those assumptions), ratings history etc. as required by the Market Abuse Regulation, can be found on UBS Neo. Different assumptions could result in materially different results.

The analyst(s) responsible for the preparation of this document may interact with trading desk personnel, sales personnel and other parties for the purpose of gathering, applying and interpreting market information. UBS relies on information barriers to control the flow of information contained in one or more areas within UBS into other areas, units, groups or affiliates of UBS. The compensation of the analyst who prepared this document is determined exclusively by research management and senior management (not including investment banking). Analyst compensation is not based on investment banking revenues; however, compensation may relate to the revenues of UBS and/or its divisions as a whole, of which investment banking, sales and trading are a part, and UBS's subsidiaries, branches and affiliates as a whole.

For financial instruments admitted to trading on an EU regulated market: UBS AG, its affiliates or subsidiaries (excluding UBS Securities LLC) acts as a market maker or liquidity provider (in accordance with the interpretation of these terms in the UK) in the financial instruments of the issuer save that where the activity of liquidity provider is carried out in accordance with the definition given to it by the laws and regulations of any other EU jurisdictions, such information is separately disclosed in this document. For financial instruments admitted to trading on a non-EU regulated market: UBS may act as a market maker save that where this activity is carried out in the US in accordance with the definition given to it by the relevant laws and regulations, such activity will be specifically disclosed in this document. UBS may have issued a warrant the value of which is based on one or more of the financial instruments referred to in the document. UBS and its affiliates and employees may have long or short positions, trade as principal and buy and sell in instruments or derivatives identified herein; such transactions or positions may be inconsistent with the opinions expressed in this document.

Global Disclaimer (continued)

United Kingdom and the rest of Europe: Except as otherwise specified herein, this material is distributed by UBS Limited to persons who are eligible counterparties or professional clients. UBS Limited is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority. **France:** Prepared by UBS Limited and distributed by UBS Limited and UBS Securities France S.A. UBS Securities France S.A. is regulated by the ACPR (Autorité de Contrôle Prudentiel et de Résolution) and the Autorité des Marchés Financiers (AMF). Where an analyst of UBS Securities France S.A. has contributed to this document, the document is also deemed to have been prepared by UBS Securities France S.A. **Germany:** Prepared by UBS Limited and distributed by UBS Limited and UBS Europe SE. UBS Europe SE is regulated by the Bundesanstalt fur Finanzdienstleistungsaufsicht (BaFin). **Spain:** Prepared by UBS Limited and distributed by UBS Limited and UBS Securities España SV, SA. UBS Securities España SV, SA is regulated by the Comisión Nacional del Mercado de Valores (CNMV). **Turkey:** Distributed by UBS Limited. No information in this document is provided for the purpose of offering, marketing and sale by any means of any capital market instruments and services in the Republic of Turkey. Therefore, this document may not be considered as an offer made or to be made to residents of the Republic of Turkey. UBS Limited is not licensed by the Turkish Capital Market Board under the provisions of the Capital Market Law (Law No. 6362). Accordingly, neither this document nor any other offering material related to the instruments/services may be utilized in connection with providing any capital market services to persons within the Republic of Turkey without the prior approval of the Capital Market Board. However, according to article 15 (d) (ii) of the Decree No. 32, there is no restriction on the purchase or sale of the securities abroad by residents of the Republic of Turkey. **Poland:** Distributed by UBS Limited (spolka z ograniczona odpowiedzialnoscia) Oddzial w Polsce regulated by the Polish Financial Supervision Authority. Where an analyst of UBS Limited (spolka z ograniczona odpowiedzialnoscia) Oddzial w Polsce has contributed to this document, the document is also deemed to have been prepared by UBS Limited (spolka z ograniczona odpowiedzialnoscia) Oddzial w Polsce. **Russia:** Prepared and distributed by UBS Bank (OOO). **Switzerland:** Distributed by UBS AG to persons who are institutional investors only. UBS AG is regulated by the Swiss Financial Market Supervisory Authority (FINMA). **Italy:** Prepared by UBS Limited and distributed by UBS Limited and UBS Limited, Italy Branch. Where an analyst of UBS Limited, Italy Branch has contributed to this document, the document is also deemed to have been prepared by UBS Limited, Italy Branch. **South Africa:** Distributed by UBS South Africa (Pty) Limited (Registration No. 1995/011140/07), an authorised user of the JSE and an authorised Financial Services Provider (FSP 7328). **Israel:** This material is distributed by UBS Limited. UBS Limited is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority. UBS Securities Israel Ltd is a licensed Investment Marketer that is supervised by the Israel Securities Authority (ISA). UBS Limited and its affiliates incorporated outside Israel are not licensed under the Israeli Advisory Law. UBS Limited is not covered by insurance as required from a licensee under the Israeli Advisory Law. UBS may engage among others in issuance of Financial Assets or in distribution of Financial Assets of other issuers for fees or other benefits. UBS Limited and its affiliates may prefer various Financial Assets to which they have or may have Affiliation (as such term is defined under the Israeli Advisory Law). Nothing in this Material should be considered as investment advice under the Israeli Advisory Law. This Material is being issued only to and/or is directed only at persons who are Eligible Clients within the meaning of the Israeli Advisory Law, and this material must not be relied on or acted upon by any other persons. **Saudi Arabia:** This document has been issued by UBS AG (and/or any of its subsidiaries, branches or affiliates), a public company limited by shares, incorporated in Switzerland with its registered offices at Aeschenvorstadt 1, CH-4051 Basel and Bahnhofstrasse 45, CH-8001 Zurich. This publication has been approved by UBS Saudi Arabia (a subsidiary of UBS AG), a Saudi closed joint stock company incorporated in the Kingdom of Saudi Arabia under commercial register number 1010257812 having its registered office at Tatweer Towers, P.O. Box 75724, Riyadh 11588, Kingdom of Saudi Arabia. UBS Saudi Arabia is authorized and regulated by the Capital Market Authority to conduct securities business under license number 08113-37. **UAE / Dubai:** The information distributed by UBS AG Dubai Branch is only intended for Professional Clients and/or Market Counterparties, as classified under the DFSA rulebook. No other person should act upon this material/communication. The information is not for further distribution within the United Arab Emirates. UBS AG Dubai Branch is regulated by the DFSA in the DIFC. UBS is not licensed to provide banking services in the UAE by the Central Bank of the UAE, nor is it licensed by the UAE Securities and Commodities Authority. **United States:** Distributed to US persons by either UBS Securities LLC or by UBS Financial Services Inc., subsidiaries of UBS AG; or by a group, subsidiary or affiliate of UBS AG that is not registered as a US broker-dealer (a **'non-US affiliate'**) to major US institutional investors only. UBS Securities LLC or UBS Financial Services Inc. accepts responsibility for the content of a document prepared by another non-US affiliate when distributed to US persons by UBS Securities LLC or UBS Financial Services Inc. All transactions by a US person in the securities mentioned in this document must be effected through UBS Securities LLC or UBS Financial Services Inc., and not through a non-US affiliate. UBS Securities LLC is not acting as a municipal advisor to any municipal entity or obligated person within the meaning of Section 15B of the Securities Exchange Act (the "Municipal Advisor Rule"), and the opinions or views contained herein are not intended to be, and do not constitute, advice within the meaning of the Municipal Advisor Rule. **Canada:** Distributed by UBS Securities Canada Inc., a registered investment dealer in Canada and a Member-Canadian Investor Protection Fund, or by another affiliate of UBS AG that is registered to conduct business in Canada or is otherwise exempt from registration. **Mexico:** This report has been distributed and prepared by UBS Casa de Bolsa, S.A. de C.V., UBS Grupo Financiero, an entity that is part of UBS Grupo Financiero, S.A. de C.V. and is a subsidiary of UBS AG. This document is intended for distribution to institutional or sophisticated investors only. Research reports only reflect the views of the analysts responsible for the reports. Analysts do not receive any compensation from persons or entities different from UBS Casa de Bolsa, S.A. de C.V., UBS Grupo Financiero, or different from entities belonging to the same financial group or business group of such. For Spanish translations of applicable disclosures, please go to www.ubs.com/disclosures. **Brazil:** Except as otherwise specified herein, this material is prepared by UBS Brasil CCTVM S.A. to persons who are eligible investors residing in Brazil, which are considered to be: (i) financial institutions, (ii) insurance firms and investment capital companies, (iii) supplementary pension entities, (iv) entities that hold financial investments higher than R$300,000.00 and that confirm the status of qualified investors in written, (v) investment funds, (vi) securities portfolio managers and securities consultants duly authorized by Comissão de Valores Mobiliários (CVM), regarding their own investments, and (vii) social security systems created by the Federal Government, States, and Municipalities. **Hong Kong:** Distributed by UBS Securities Asia Limited and/or UBS AG, Hong Kong Branch. Please contact local licensed/registered representatives of UBS Securities Asia Limited and/or UBS AG, Hong Kong Branch in respect of any matters arising from, or in connection with, the analysis or document. **Singapore:** Distributed by UBS Securities Pte. Ltd. [MCI (P) 008/09/2017 and Co. Reg. No.: 198500648C] or UBS AG, Singapore Branch. Please contact UBS Securities Pte. Ltd., an exempt financial adviser under the Singapore Financial Advisers Act (Cap. 110); or UBS AG, Singapore Branch, an exempt financial adviser under the Singapore Financial Advisers Act (Cap. 110) and a wholesale bank licensed under the Singapore Banking Act (Cap. 19) regulated by the Monetary Authority of Singapore, in respect of any matters arising from, or in connection with, the analysis or document. The recipients of this document represent and warrant that they are accredited and institutional investors as defined in the Securities and Futures Act (Cap. 289). **Japan:** Distributed by UBS Securities Japan Co., Ltd. to professional investors (except as otherwise permitted). Where this document has been prepared by UBS Securities Japan Co., Ltd., UBS Securities Japan Co., Ltd. is the author, publisher and distributor of the document. Distributed by UBS AG, Tokyo Branch to Professional Investors (except as otherwise permitted) in relation to foreign exchange and other banking businesses when relevant. **Australia:** Clients of UBS AG: Distributed by UBS AG (ABN 47 088 129 613 and holder of Australian Financial Services License No. 231087). Clients of UBS Securities Australia Ltd: Distributed by UBS Securities Australia Ltd (ABN 62 008 586 481 and holder of Australian Financial Services License No. 231098). This Document contains general information and/or general advice only and does not constitute personal financial product advice. As such, the Information in this document has been prepared without taking into account any investor's objectives, financial situation or needs, and investors should, before acting on the Information, consider the appropriateness of the Information, having regard to their objectives, financial situation and needs. If the Information contained in this document relates to the acquisition, or potential acquisition of a particular financial product by a 'Retail' client as defined by section 761G of the Corporations Act 2001 where a Product Disclosure Statement would be required, the retail client should obtain and consider the Product Disclosure Statement relating to the product before making any decision about whether to acquire the product. The UBS Securities Australia Limited Financial Services Guide is available at: www.ubs.com/ecs-research-fsg. **New Zealand:** Distributed by UBS New Zealand Ltd. UBS New Zealand Ltd is not a registered bank in New Zealand. You are being provided with this UBS publication or material because you have indicated to UBS that you are a "wholesale client" within the meaning of section 5C of the Financial Advisers Act 2008 of New Zealand (Permitted Client). This publication or material is not intended for clients who are not Permitted Clients (non-permitted Clients). If you are a non-permitted Client you must not rely on this publication or material. If despite this warning you nevertheless rely on this publication or material, you hereby (i) acknowledge that you may not rely on the content of this publication or material and that any recommendations or opinions in such this publication or material are not made or provided to you, and (ii) to the maximum extent permitted by law (a) indemnify UBS and its associates or related entities (and their respective Directors, officers, agents and Advisors) (each a 'Relevant Person') for any loss, damage, liability or claim any of them may incur or suffer as a result of, or in connection with, your unauthorised reliance on this publication or material and (b) waive any rights or remedies you may have against any Relevant Person for (or in respect of) any loss, damage, liability or claim you may incur or suffer as a result of, or in connection with, your unauthorised reliance on this publication or material. **Korea:** Distributed in Korea by UBS Securities Pte. Ltd., Seoul Branch. This document may have been edited or contributed to from time to time by affiliates of UBS Securities Pte. Ltd., Seoul Branch. This material is intended for professional/institutional clients only and not for distribution to any retail clients. **Malaysia:** This material is authorized to be distributed in Malaysia by UBS Securities Malaysia Sdn. Bhd (Capital Markets Services License No.: CMSL/A0063/2007). This material is intended for professional/institutional clients only and not for distribution to any retail clients. **India:** Distributed by UBS Securities India Private Ltd. (Corporate Identity Number U67120MH1996PTC097299) 2/F, 2 North Avenue, Maker Maxity, Bandra Kurla Complex, Bandra (East), Mumbai (India) 400051. Phone: +912261556000. It provides brokerage services bearing SEBI Registration Numbers: NSE (Capital Market Segment): INB230951431, NSE (F&O Segment) INF230951431, NSE (Currency Derivatives Segment) INE230951431, BSE (Capital Market Segment) INB010951437; merchant banking services bearing SEBI Registration Number: INM000010809 and Research Analyst services bearing SEBI Registration Number: INH000001204. UBS AG, its affiliates or subsidiaries may have debt holdings or positions in the subject Indian company/companies. Within the past 12 months, UBS AG, its affiliates or subsidiaries may have received compensation for non-investment banking securities-related services and/or non-securities services from the subject Indian company/companies. The subject company/companies may have been a client/clients of UBS AG, its affiliates or subsidiaries during the 12 months preceding the date of distribution of the research report with respect to investment banking and/or non-investment banking securities-related services and/or non-securities services. With regard to information on associates, please refer to the Annual Report at: http://www.ubs.com/global/en/about_ubs/investor_relations/annualreporting.html **Taiwan:** Distributed by UBS Securities Pte. Ltd., Taipei Branch which is regulated by the Taiwan Securities and Futures Bureau.

The disclosures contained in research documents produced by UBS Limited shall be governed by and construed in accordance with English law.

Contact information

UBS Limited
5 Broadgate
London
EC2M 2QS

Tel: +44-207-567 8000

www.ubs.com

UBS