

Crowding

Man Group Academic Advisory Board

February, 2019

OVERVIEW

- **The concept of crowding can be difficult to define.** Broadly, it describes the tendency of investors to act in similar ways in response to the same stimuli, leading to overlapping trading positions.
- **The causes of crowding are many and varied.** They range from investors analysing the same data sets with the same techniques, to the ubiquitous use of similar risk management systems, to the rise of passive investing giving retail investors more access to financial markets.
- **Measuring crowding is easiest in cash equities,** where we have access to the holdings data of other investors. For other strategies, looking at short term correlations can help gauge the levels of crowding.
- **The effects of crowding are broadly two-fold.** On the one hand, crowding in a strategy can lead to diminished expected returns, whilst on the other, crowding can increase the risk of liquidity-driven tail events.
- **Some strategies are more susceptible to crowding than others.** Heavily rules-based trading is most at risk if it leads to a concentration of investors acting in the same way at the same time.
- **Modelling crowding can be useful for investment managers.** Research in cash equities suggests that substituting crowded positions in a portfolio with similar, less-crowded stocks may improve the returns profile. The difficulty is in producing an instantaneous measure of crowding.
- **Crowding can create opportunities.** The short interest factor is a crowding-based measure that has been profitable in cash equities. Predictable trading around passive index rebalancing also presents potential opportunities for active investors.
- **Managers must be proactive about crowding.** It is important that managers are disciplined by keeping within the feasible capacities of their strategies, as well as monitoring the impact that crowding has on their overall returns.

CONTENTS

Introduction	3
Agenda	3
The Discussion	4
Important Information	9

www.man.com
www.oxford-man.ox.ac.uk

INTRODUCTION

Crowding has become one of the foremost concerns in the minds of investors, particularly in quantitative strategies. The concept of crowding is often ill-defined, but the issues that it raises are important. How does crowding impact the expected returns of a strategy? Does crowding increase the likelihood of tail events? Which strategies are most impacted by crowding?

These questions were amongst those discussed by the Man Group Academic Advisory Board during their most recent meeting in Boston. The board also discussed the wider effects of crowding on Man Group's business, and the steps that are taken to address them.

The board, whose members bring a diverse range of perspectives and deep expertise, consists of:

- **Nicholas Barberis**
Professor of Finance at the Yale School of Management
- **Campbell Harvey**
Professor of Finance at the Fuqua School of Business at Duke University, and Editor of the Journal of Finance from 2006-2012
- **Neil Shephard**
Frank B. Baird, Jr, Professor of Science, Professor of Economics and Statistics, Harvard University. Neil was the founding director of the Oxford-Man Institute of Quantitative Finance in Oxford and directed it from 2007–2011

Joining the academics on the board were researchers, portfolio managers and senior leadership from across Man Group:

- **Greg Bond**
Director of Research, Man Numeric
- **Ed Fang**
Deputy Director of Research, Man Numeric
- **Otto Hamaoui**
Partner in Equity Research, Man AHL
- **Otto van Hemert**
Head of Macro Research, Man AHL
- **Neil Mason**
Head of European Equity Long-Short, Man GLG
- **Shanta Puchtler**
CEO, Man Numeric
- **Matthew Sargaison**
Co-CEO, Man AHL
- **Dan Taylor**
Co-CIO, Man Numeric
- **David Ryan**
Quantitative Analyst

AGENDA

1. What Is Crowding and How Do We Define It?
2. What Are the Main Causes of Crowding?
3. How Can We Observe, and Measure, Crowding?
4. What Are the Effects of Crowding?
5. Are Some Strategies More Susceptible to Crowding Than Others?
6. Can We Model Crowding to Draw Useful Conclusions for Our Trading?
7. Does Crowding Create Opportunities, as Well as Risks?
8. What Questions Should Investors Be Asking About Crowding?
9. What Questions Should Regulators Be Asking About Crowding?

THE DISCUSSION

1. What Is Crowding and How Do We Define It?

Campbell Harvey (CH): Crowding is an interesting topic, precisely because it is difficult to define. Crowding, from an academic perspective, does not have an established body of knowledge behind it, which makes it particularly important for us to try to understand.

At a very high level, we can think of crowding as the tendency of investors to focus on a similar set of factors, strategies, or securities. This behaviour manifests itself as an observed high correlation between both the holdings and returns of managers.

Nicholas Barberis (NB): As well as investors holding similar positions, crowding is also to do with these investors acting in the same way, at the same time, for the same reasons.

We often think of crowding as being exclusively amongst relatively sophisticated market participants, such as hedge funds or mutual funds. What makes these groups of investors special, from a crowding perspective, is that they often share similar trading and forced liquidation criteria, and so are liable to act in similar ways during periods of market stress.

Otto van Hemert (OvH): There is also a difference between crowding in a strategy, and crowding in an asset. In a strategy, we have a situation where many market participants are looking at similar potential alphas, and so are exposed to similar risks. In an asset, we have traders of a similar style all holding the same position in a market, and so there is the risk that they all unwind at the same time.

Dan Taylor (DT): Crowding has several sides to it – the definition can be very different depending on the circumstances. From a quant equity perspective, for instance, we often view crowding as a potential source of alpha. Ranking companies in the cross-section based on their levels of short interest is a crowding-based factor that has been used as a trading strategy for a prolonged period of time.

Otto Hamaoui (OH): It is important to include reference points when we define crowding. A strategy, for instance, will only be crowded when the level of arbitrageur capital deployed in it is large relative to the capacity that the strategy could feasibly sustain. This capacity will be different for different strategies, and is crucial to gauge.

Market liquidity is also important in determining how crowded a strategy or market can become. For the effects of crowding to be seen, we need the group of crowded investors to be large enough to have a material market impact when they act simultaneously.

2. What Are the Main Causes of Crowding?

Shanta Puchtler (SP): The single largest contributor to crowding is the simple fact that investors tend to do the same sorts of things. There is a real propensity for investors to analyse the same datasets, with the same statistical techniques, and hence end up with largely overlapping positions.

This effect is exacerbated by the fact that investors have a bias to chase returns from different strategies. After a period of good performance, assets will tend to flow into a strategy (and vice-versa) after a period of bad performance. This leads to assets pooling into strategies that have performed well in the recent past.

Matthew Sargaison (MS): These behavioural biases are a key component in understanding the causes of crowding. If investors update their trading depending on the actions they have seen in the market before them, this can lead to the cascade-type of behaviour that we often associate with crowding.

OH: We see this type of behaviour in the predictions of sell-side analysts, which tend to cluster around a similar set of consensus opinions. This will ultimately reinforce similar trade ideas with investors.

Another cause of crowding is the ubiquitous use of standard portfolio construction techniques amongst investment managers. Firstly, techniques such as risk parity rebalancing or volatility scaling can lead to the synchronicity in trading behaviour that we often associate with crowding.

Secondly, the use of similar risk models may lead to a situation where managers are loading up on a very similar set of risk factors, increasing the overlap of their exposures.

Neil Mason (NM): Within GLG, we take active steps to try to mitigate the dangers associated with this. Our portfolio managers specifically build their portfolios to be predominantly composed of idiosyncratic risks, limiting how much we load onto factors that are spanned by traditional risk models.

The caveat is that it is hard to measure exactly what your idiosyncratic risk is, and there is the danger that you are just loaded onto hidden factors. This potential for mismeasurement is another source of crowding, if investors underestimate the extent to which they are exposed to common factors that only become apparent during periods of market stress.

Neil Shephard (NS): The constant turnover of the investment professionals who manage money on an institutional scale may add to this effect.

Each new generation of managers may get overconfident about their ability to identify, measure, and manage risks,

which subsequently leads them to crowd into similar trades.

MS: We often think of it as the actions of active investors that lead to crowding, but the large increase in passive investing may also have a significant effect. The rise of ETFs has given retail investors far more opportunity to invest in factors, such as value or size, which they may not have been able to access in the past, which could lead to increased crowding. The crash of the short volatility trade in February 2018 may have been an example of this.

Greg Bond (GB): The causes of crowding we have discussed may actually become more acute in the future. The ease of access to data, computing power, and even leverage has increased dramatically in recent years, lowering the barriers to entry for people to start analysing datasets with similar basic models.

We are also continuing to see a convergence between quantitative and discretionary investment managers. Discretionary managers are increasingly using quantitative techniques, and quantitative managers are starting to use fundamental datasets in their analysis. If this trend persists, then we could see more crowding between managers.

3. How Can We Observe, and Measure, Crowding?

Ed Fang (EF): In the cash equity space, we have several metrics that we can use to try to quantitatively measure the crowding in a trade. On the long side, we can use 13-F filings data to look at the holdings of large, US-based asset managers. Typically, we are most interested in looking at how similar our holdings are to managers with a similar investment style. This gives us an idea of how susceptible we are to a risk event where we are all forced to act in a certain way.

On the short side, we can look at short interest data. We would usually look at the utilisation ratio of a stock – the ratio of the number of shares in that stock that are being borrowed by short sellers to the total volume of shares traded. In the cross-section, this gives a good gauge of which stocks are crowded, and which are not.

NM: At Man GLG, we have observed that high utilisation stocks historically exhibit far more negative skew than low utilisation stocks. This is because the crowded, high-utilisation stocks are more prone to being dumped during a deleveraging event.

SP: Another thing to look at is the extent to which your portfolio gets pushed around by flows at the end of the month as people rebalance their positions. At Man Numeric, in the lead up to the quant crisis in August 2007, we were seeing returns generated in our portfolios due to flows coming into similar strategies. This may

have been a forewarning that quant equity was becoming crowded.

OvH: A similar thing has been noted in the CTA space. Until around 2012, a large percentage of the returns in futures momentum could be attributed to the few days around the end of the month when flows would typically enter the strategy, causing managers to trade up their existing positions and temporarily push prices in their favour. This effect has not been observed after 2012 as flows into CTAs have plateaued, suggesting that crowding has potentially not gotten out of hand.

MS: Within Man AHL, much of our trading is in futures and forward contracts, where we do not have the luxury of 13-F filings data. What we can look at, particularly in our momentum strategies, is simply the strength of the signal.

When we analyse the tails of the distribution for our momentum signals, we find that there is more information about the unrealised volatility in a market, rather than a directional prediction. This observation suggests that the profitability of trend following decreases as crowding into the trend becomes more extreme. To try to account for this, our momentum strategies all utilise response functions such that we actually cut our exposure to a market if we detect crowding in this way.

NB: There are other techniques to measure crowding that have been used in the academic literature – one is to look at correlation data. Take, for example, a strategy trading in cash equities. If we observe an increase in the intra-day correlation between equities in the top bucket of that strategy, or between equities in the bottom bucket, then that may suggest that there are many participants following the strategy, all buying and selling at the same time.

Finally, given the multi-faceted nature of crowding, it is not obvious that you want to use the same measure of crowding in all instances.

If you are interested in the tail risks that crowding may introduce, then 13-Fs and other holdings data may be the most important measure, as these give you an idea of the positions of investors that face similar risks to yourself.

On the other hand, if you are interested in the impact of crowding on the alpha of a strategy, correlation measures may be a more direct measure of the impact crowding has on returns.

4. What Are the Effects of Crowding?

CH: Firstly, crowding can lead to alpha decay. Simply, a strategy may become less profitable as more and more people engage in it. This may be because the

opportunities for arbitrage are closed much more quickly when there are many people trying to exploit them.

Secondly, crowding can increase the tail risks of a trade. If there are many participants crowded into a trade, then you may get a rush to the exit if a shock to the system forces everyone to close their positions at the same time.

GB: Both aspects can be dangerous in their own way. Left tail events can be very acute in a very short space of time, while alpha decay is a much slower process, making it harder to detect.

DT: If we look back to the quant crisis in August 2007, assets had built up in quantitative equity strategies over a period of many years, which made the crowding harder to notice than, say, the rapid inflows into bitcoin.

The quant crisis highlighted another risk of crowding – that left tail drawdowns can be triggered by exogenous events. The catalyst for the losses incurred by quant equity funds in August 2007 was the closing of a credit trading desk that also traded an equity portfolio. The subsequent liquidation of these positions caused turmoil as funds with very similar, highly levered positions were forced up against margin limits.

CH: Crowding may positively impact market efficiency. For instance, if investors crowd into a trade that exploits a mispricing, this may reduce the deviation from fair value.

OvH: This is only true up to a point. Crowding into trends, for instance, may drive prices far away from their fair value, and this would be a destabilising effect.

NB: There is an interesting “limits to arbitrage” argument here. If crowding makes investors more wary of increased tail risks then that may increase the limits to arbitrage of a trade, preserving some of the potential alpha that can be earned by those who assume the risks.

NS: The increased tail risks that crowding causes in financial markets are also interesting, because it is not an effect that is typically seen when there is increased competition in other industries. In most businesses, a more competitive environment will usually lead to lower profitability for companies, an alpha decay, but it is not obvious that it increases the likelihood of a systemic shock to the industry. Why do we think that finance is different?

SP: The ubiquitous use of leverage is possibly something that makes finance unique, and certainly exaggerates the risk of fire-sales when crowded trades unwind.

There is a dangerous feedback loop that as crowding decreases the profitability of a trade, participants may be forced to use more leverage to keep exploiting it, which may in turn lead to an increased risk of a liquidity event.

CH: Finally, it is important to understand how crowding may affect the properties of a strategy. Many investors, for example, value time-series momentum strategies as they have historically provided a hedge during equity downturns. We would like to be confident that these properties will persist, even if the strategy becomes crowded.

5. Are Some Strategies More Susceptible to Crowding Than Others?

OvH: One way to look at this is to split strategies into those that are anchored, and those that are unanchored. An anchored strategy is one that has an observable reference for fair value. Take the equity value factor for instance, where we can observe the spread between cheap and expensive stocks. If this spread is historically tight, that would suggest that there has been crowding into value trading, and this may act as a natural defence to crowding getting out of control.

In an unanchored strategy such as momentum, however, there is no obvious proxy for fair value. This may make these strategies more susceptible to crowding, because it is difficult to observe how much capital is deployed in them. Indeed, in this type of strategy you may even increase your position as crowding increases and prices move in your favour.

GB: This will depend on whether investors are using the same models and benchmarks when constructing their strategies. For instance, market participants do not agree on the best metric for calculating equity value, and so it is still not clear what the anchor here is.

Instead, it may be that the strategies that are at most risk of crowding are those that are very homogenous, with little debate about what the parameterisation should be.

NS: It is this homogeneity that makes crowding dangerous in any rules-based trading strategy. As we have discussed, the mal-effects of crowding aren't simply the product of investors holding similar positions, but rather from this group acting in a very formulaic way in response to the same stimulus, leading to a concentration of actions at a precise point in time.

MS: There is a danger of runaway crowding in assets where the fundamental value is very unclear. If we look at the technology bubble of 2001, or the recent bitcoin bubble, it was a complete uncertainty about where assets should be priced that helped to feed the levels of crowding.

OH: If we are concerned about the negative skew effects of crowding, then it is those strategies that inherently require a large amount of leverage that are most at risk.

EF: We can also incorporate the typical investment horizon of a strategy. Those strategies that have a long holding period are likely less prone to negative skew

events because they do not trade on a fast enough time scale for these to be important.

SP: Looking forward, it is interesting to think of the effects of crowding on things like machine learning strategies, which are increasingly being used to automate the search for alpha.

From one perspective, these strategies might be more susceptible to crowding as the idiosyncratic human element of the investment process is lost. It may also become harder to notice that you are trading in a similar way to your peers because of the black-box nature of these algorithms.

DT: On the other hand, machine learning algorithms typically have a vast number of degrees of freedom, and allow you to explore relationships between vastly bigger data sets. This move away from analysing a small number of data sources in a very standardised way may actually lead to less overlap in traders' positions.

6. Can We Model Crowding to Draw Useful Conclusions for Our Trading?

NB: There are several pieces of work in the academic literature that attempt to use agent based models to predict market dynamics in the presence of crowding. For instance, some research looks into the competition between value and momentum traders as the number of agents is varied.

The issue with these models, from a practical standpoint, is that they are very sensitive to the initial choices made when setting up the problem.

EF: At Man Numeric, we have already done some work on trying to model crowding at the individual market level. We found that if you replaced the most crowded stocks in your portfolio with stocks that had very similar factor exposures, but were less crowded, then you maintained most of your alpha, but with an improved risk profile.

The catch to this is that the research required you to have instantaneous knowledge of the level of crowding in a stock. This is not possible in practice if you are using 13-F filings data, which is only available after a considerable lag. The research does, however, highlight the value of having a clear understanding of which positions in your portfolio are potentially crowded.

NM: In the Man GLG equity long-short business, we have also gauged the impact that crowding could have on our portfolios by modelling how long it would take us to reasonably unwind our positions. We then try to avoid building into positions that would be painful to get out of during a liquidity event.

Another way to try to measure the presence of crowding is to look for situations in which your usual risk metrics

break down. For instance, if the difference between the volatility of your portfolio that you get from a factor model is wildly different from that which you get from a PCA model, this might be an indication that something is not quite right, and you may want to de-risk.

NS: An idea for more speculative research would be to try to model the dynamics of exactly how managers change their positions in response to periods of market stress. This would give you an insight into how the actual effects of crowding play out.

This may also allow us to stress test our portfolios to the effects of crowding, and allocate to them accordingly depending on how much tail risk they have.

EF: The difficulty here will be that tail events are very rare, and so are incredibly hard to model. Even if you could predict the dynamics of a liquidity event, predicting the timing would be very tricky – you would get lots of false positives.

7. Does Crowding Create Opportunities, as Well as Risks?

MS: At face value, it is not obvious that crowding is necessarily a bad thing for strategies such as momentum. Crowding may temporarily drive prices in the favour of momentum traders, although this may then be accompanied by a painful, sharp reversal once it becomes clear that prices have become dislocated.

At Man AHL, we have investigated whether we observe this pattern of exaggerated trends followed by sharp corrections in the markets that we trade. The fact that we do not find this behaviour suggests to us that futures momentum may not be as overcrowded at present as investors fear.

NM: Crowding, specifically crowding into passive investment strategies, has also created opportunities for active investors. Around a rebalancing event, for example, passive flows can become very predictable, and we have seen an increased number of arbitrageurs attempting to profit from this.

It should also be appreciated that some level of crowding is welcomed by a trader in order to monetise their trades. A good investor will attempt to buy into a position before it becomes popular, and then the herding behaviour of latecomers to the trade may provide welcome liquidity for the investor to exit the position.

GB: Similarly, from the quant equity perspective, we have already discussed how being long crowding via the short-interest factor has been a historically successful strategy. When we look at the payoff from this factor, returns increase very linearly with the magnitude of the signal – you really have, on average, been rewarded for holding crowded positions historically. As long as you

stay diversified, the exposure to negative skew events can potentially be mitigated.

More speculatively, given the discussion that we have had on the dangers of crowding and leverage, could you look to profit from crowding by holding an amount of capital in cash assets, and then using it to provide liquidity to the market during the unwinds of crowded trades?

DT: Liquidity provision would likely be profitable, but the issue would be the huge opportunity cost that you forgo by not being invested during the long periods of normal market behaviour.

8. What Questions Should Investors Be Asking About Crowding?

CH: As an investor, I would like my managers to be very proactive in thinking about crowding. It would be a red flag if I were to go to a manager and they did not have a well-defined idea of what the capacities of their strategies are. More than this, it is important that managers stick to these limits.

OvH: These capacity concerns have become increasingly important as we continue to see consolidation in the asset management industry. Moving from a performance fee to a management fee driven business potentially promotes asset gathering amongst managers, which makes abiding by capacity constraints very important to avoid crowding.

MS: It is key that managers have a clear understanding of how crowding impacts their performance, either positively or negatively. Having a metric in place to track this exposure to crowding is very important. I think it would also be good for a manager to understand how crowding impacts the implementation of their strategies; for instance whether increased crowding increases the cost of trading.

For quantitative managers, it is important to appreciate the danger of back-testing strategies during historical periods when there may have been less crowding. Not relying too rigidly on the conclusions drawn from tests on past data could help to limit this risk.

DT: Similarly, it would be good for managers to be able to point to measures that they have taken ex-ante to respond to crowding. It is very easy to come up with an after-the-fact model that would have avoided exposure to a particular liquidity event, but proving that a manager is thinking pre-emptively about these things would be a positive in my view.

GB: I believe that one of the most important factors in helping to counter the alpha-decay aspect of crowding is to find a manager that is constantly innovating and trying to create new alphas. This is precisely why we invest so heavily in producing new research to try to improve the models that we run.

SP: More than this, innovation also requires some conviction from a manager. I think that a manager needs to be bold enough to incorporate new, perhaps unproven, alphas in their portfolios, as well as to down-weight more traditional strategies if the evidence is there that their alpha potential has been degraded.

9. What Questions Should Regulators Be Asking About Crowding?

DT: We have discussed how crowding can lead to exogenous events triggering market sell-offs, such as in the 2007 quant crisis. I would want regulators to try to understand the dynamics that can lead to this type of contagion in crowded markets.

GB: In order to understand these dynamics, perhaps it would be helpful for regulators to increase the frequency with which large institutions have to report their positions. This would give the regulators increased transparency, and allow them to act more quickly if there was a danger of market instability.

CH: More radically, and not that I am advocating this, introducing a tax on transactions might incentivise investors to take a more long-term view, which would help to avoid some of the pitfalls of crowding. That said, there are definite downsides to such a tax.

NM: Indeed, there are already markets – such as Hong Kong, Taiwan, and Korea – where such taxes exist. What we see is that it leads to slower price discovery, so you would need to be careful that attempts to address one problem don't just create new ones.

SP: Countering the destabilising effects of crowding should be a priority for regulators, in my view. Limiting market participants' access to liquidity, or capping the percentage of the volume of an asset that a single investor can hold could potentially dissuade people from crowding into dangerous positions.

On the other hand, though, regulators should perhaps welcome some aspects of crowding. The increased competition that leads to the alpha-decay of strategies, and hence more efficient markets, could be viewed as a good thing. This should then be the spur for us practitioners to continue doing research to try to uncover less crowded sources of excess return.

IMPORTANT INFORMATION

This information is communicated and/or distributed by the relevant Man entity identified below (collectively the 'Company') subject to the following conditions and restriction in their respective jurisdictions.

Opinions expressed are those of the author and may not be shared by all personnel of Man Group plc ('Man'). These opinions are subject to change without notice, are for information purposes only and do not constitute an offer or invitation to make an investment in any financial instrument or in any product to which the Company and/or its affiliates provides investment advisory or any other financial services. Any organisations, financial instrument or products described in this material are mentioned for reference purposes only which should not be considered a recommendation for their purchase or sale. Neither the Company nor the authors shall be liable to any person for any action taken on the basis of the information provided. Some statements contained in this material concerning goals, strategies, outlook or other non-historical matters may be forward-looking statements and are based on current indicators and expectations. These forward-looking statements speak only as of the date on which they are made, and the Company undertakes no obligation to update or revise any forward-looking statements. These forward-looking statements are subject to risks and uncertainties that may cause actual results to differ materially from those contained in the statements. The Company and/or its affiliates may or may not have a position in any financial instrument mentioned and may or may not be actively trading in any such securities. This material is proprietary information of the Company and its affiliates and may not be reproduced or otherwise disseminated in whole or in part without prior written consent from the Company. The Company believes the content to be accurate. However accuracy is not warranted or guaranteed. The Company does not assume any liability in the case of incorrectly reported or incomplete information.

Unless stated otherwise all information is provided by the Company. Past performance is not indicative of future results.

Unless stated otherwise this information is communicated by Man Solutions Limited which is registered in England and Wales at Riverbank House, 2 Swan Lane, London, EC4R 3AD. Authorised and regulated in the UK by the Financial Conduct Authority.

Australia: To the extent this material is distributed in Australia it is communicated by Man Investments Australia Limited ABN 47 002 747 480 AFSL 240581, which is regulated by the Australian Securities & Investments Commission ('ASIC'). This information has been prepared without taking into account anyone's objectives, financial situation or needs.

European Economic Area: Unless indicated otherwise this material is communicated in the European Economic Area by Man Solutions Limited which is an investment company as defined in section 833 of the Companies Act 2006 and is authorised and regulated by the UK Financial Conduct Authority (the 'FCA'). Man Solutions Limited is registered in England and Wales under number 3385362 and has its registered office at Riverbank House, 2 Swan Lane, London, EC4R 3AD, England. As an entity which is regulated by the FCA, Man Solutions Limited is subject to regulatory requirements, which can be found at <http://register.fca.org.uk>.

Germany: To the extent this material is used in Germany, the communicating entity is Man (Europe) AG, which is authorised and regulated by the Liechtenstein Financial Market Authority ('FMA'). Man (Europe) AG is registered in the Principality of Liechtenstein no. FL-0002.420.371-2. Man (Europe) AG is an associated participant in the investor compensation scheme, which is operated by the Deposit Guarantee and Investor Compensation Foundation PCC (FL-0002.039.614-1) and corresponds with EU law. Further information is available on the Foundation's website under www.eas-liechtenstein.li. This material is of a promotional nature.

Hong Kong: To the extent this material is distributed in Hong Kong, this material is communicated by Man Investments (Hong Kong) Limited and has not been reviewed by the Securities and Futures Commission in Hong Kong. This material can only be communicated to intermediaries, and professional clients who are within one of the professional investor exemptions contained in the Securities and Futures Ordinance and must not be relied upon by any other person(s).

Liechtenstein: To the extent the material is used in Liechtenstein, the communicating entity is Man (Europe) AG, which is regulated by the Financial Market Authority Liechtenstein ('FMA'). Man (Europe) AG is registered in the Principality of Liechtenstein no. FL-0002.420.371-2. Man (Europe) AG is an associated participant in the investor compensation scheme, which is operated by the Deposit Guarantee and Investor Compensation Foundation PCC (FL-0002.039.614-1) and corresponds with EU law. Further information is available on the Foundation's website under www.eas-liechtenstein.li.

Switzerland: To the extent this material is distributed in Switzerland, this material is communicated by Man Investments AG, which is regulated by the Swiss Financial Market Authority FINMA.

United States: To the extent his material is distributed in the United States, it is communicated and distributed by Man Investments, Inc. ('Man Investments'). Man Investments is registered as a broker-dealer with the SEC and is a member of the Financial Industry Regulatory Authority ('FINRA'). Man Investments is also a member of the Securities Investor Protection Corporation ('SIPC'). Man Investments is a wholly owned subsidiary of Man Group plc. The registration and memberships described above in no way imply a certain level of skill or expertise or that the SEC, FINRA or the SIPC have endorsed Man Investments. Man Investments, 452 Fifth Avenue, 27th fl., New York, NY 10018.

This material is proprietary information and may not be reproduced or otherwise disseminated in whole or in part without prior written consent. Any data services and information available from public sources used in the creation of this material are believed to be reliable. However accuracy is not warranted or guaranteed. © Man 2019