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Hedge funds

Statistical arbitrage, high frequency trading and their consequences for the environment of businesses

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Abstract

Purpose – The paper's aim is to explore the impact of statistical arbitrage and high-frequency trading as hedge fund investment strategies that have a significant impact on the environment of corporations.

Design/methodology/approach – The paper is a meta-analysis of the role of investment strategies within complex systems.

Findings – The growth of hedge fund investment activity based on statistical arbitrage tends to produce a vulnerability; more funds using the strategy helps to create the profitable outcomes that the strategy relies upon. However, the growth also reduces the time lines of profitability and produces an underlying instability based on overlapping holdings and the use of leverage. The shortened timelines also create a further impetus towards technological competition and promotes high frequency trading, which then introduces further vulnerabilities based on "stop-loss cascades".

Research limitations/implications – Much of the trading creates a superficial form of liquidity, which gives a limited sense of market vulnerabilities. The basis of complex interactions between high frequency traders is also not clearly understood. Researchers and agents of policy ought to pay greater attention to the issues than is currently the case.

Originality/value – The area is one that is under-researched.

Keywords Hedge funds, Statistical arbitrage, High frequency trading, Financialisation

Paper type Research paper

The total of global financial assets (equities, private and public debt, and bank deposits) in recent years has approached $200 trillion (Roxburgh *et al.*, 2009). Hedge fund assets under management, meanwhile, have varied over the last four years, from a low of $1.33 trillion to around $2 trillion (Hedge Fund Research, 2011a). So far as is known, therefore, hedge fund assets are around 1 per cent of the total.

In this paper, the starting point for the analysis involves recognition that, although hedge funds command only a small proportion of global capital, they exert influence that is greatly disproportionate to their size. It will be argued here that in some very clear ways hedge funds can be seen as pivotal financial agents. As the G7/BIS Financial Stability Forum (FSF) has noted regarding hedge funds:

> Although the aggregate assets under management are small relative to the total size of the global equity and debt markets, and even to those of more traditional institutional investors [which total around $90 trillion] their share of trading volume in many market segments, particularly more complex ones, is much larger than their share of assets (Financial Stability Forum, 2007, p. 8).

Various writers and researchers have translated this greater than proportional significance into specifics. According to Stulz, for example, by 2006, hedge funds

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accounted for an estimated 50 per cent of trading on the London and New York Stock exchanges (Stulz, 2007, p. 175)[1]. In 2007, Stalmann and Knips (see Murphy, 2007) estimated that hedge funds were responsible for around 65 per cent (approximately $300bn) of total worldwide margin debt. That debt was acquired whilst engaged in trade that constituted between 25 per cent and 60 per cent of the activity on various asset markets (including equity markets). In 2009 and 2010 Sangston, an analyst at the consultancy firm Greenwich Associates, estimated on the basis of a sampling process that hedge fund trading activity peaked in 2007 at 29 per cent of all US fixed income asset trading, 80 per cent of high yield credit derivatives, 20 per cent of mortgage-backed securities and 29 per cent of trade volumes in US government bonds (Greenwich Associates, 2009, 2010).

Added to this, the hedge fund "industry" is a relatively concentrated one, and increasingly so. In 2003, the top 100 hedge funds accounted for 54 per cent of total assets under management. By 2010 this had risen to just under 70 per cent of total assets (Maslakovic, 2011, pp. 5-6). That is, 70 per cent of approximately $1.9 trillion of assets under management in 2010 was accounted for by 100 in a total of around 9,000 funds. The majority of capital allocated to hedge funds, then, is managed by less than 1 per cent of the total number of funds. By extension, and importantly, these funds account for a significant proportion of total trading activity in financial markets represented by hedge funds. And they do so based on leverage levels that are recognised to be higher than is average for hedge funds in general (averaging around 4:1, but increasing to over 20; Hedge Fund Research, 2011b). The magazine *Institutional Investor* produces data on the top 100 hedge funds every year. Excluding funds of funds (which invest in other hedge funds), in both 2010 and 2011 the top 12 hedge funds each had assets under management exceeding $20bn. Bridgewater Associates was number one in 2011 with $58.9bn in assets under management. The top 20 included Paulson & Co., GLG Partners (a subsidiary of MAN since 2010), Och-Ziff Capital Management Group, BlackRock, Renaissance Technologies Corporation (Medallion), and Landsdowne Partners, as well as the bank units JP Morgan Asset Management and Goldman Sachs Asset Management (Institutional Investor, 2012).

Hedge funds then were significant financial actors at the time of the global financial crisis and have not subsequently gone away or changed what they do. The extent to which hedge funds were implicated in the global financial crisis is not well understood, and some comments on this and the contribution of hedge funds to financial instability more generally will be considered in this paper. However, it is clear that hedge funds form an increasingly important aspect of the environment of publicly traded companies. Both of these points suggest the importance of understanding more about them and how they operate. Understanding the way in which hedge funds generate returns to their investors is an important aspect of understanding the dynamics of the finance system.

Hedge fund activities and arbitrage

The term "hedge fund" has an institutional and conventional meaning rather than a legal definition (see also Fichtner, 2013). Hedge funds involve a loose set of organisational characteristics adopted to position the owners or managers of the fund to secure maximum freedom to engage in investment with minimum restrictions (Riviere, 2010; Erturk *et al.*, 2010). Thus, although there have been various attempts to classify hedge funds according to their different activities (see, for example, Fichtner,

2013; Coggan, 2008), in many ways this exercise is self-defeating as one of the most characteristic features of these funds is their ability to change investment strategies. Thus, hedge funds pursue a variety of investment strategies and may follow several at the same time or move between them – in a sequence or not. What hedge funds actually do is highly contingent, adapting to different opportunities for profit. Since the early 2000s hedge funds have frequently diversified into private equity finance territory and, more recently still, have responded to the global financial crisis by moving into sovereign debt speculation and also debt market exploitation in general. Some have become so-called "vulture funds".

However, in this paper the focus will be on what can be considered a core or basic activity of hedge funds, which is arbitrage and quasi-arbitrage forms of profit-making. In its basic form, arbitrage is the practice of spotting a discrepancy in the value of an asset being sold in different markets and using this difference to make a profit. The basic operation involves buying an asset relatively cheaply in one market and selling it more expensively in another. Looked at in this way, the arbitrager is a specialist type of trader who, as all traders do, attempts to exploit the relative scarcities of commodities in different locations. The difference in this form of trading is that it is actually risk-free if expediently executed. The profit opportunity is in a difference of prices, which definitely exists, and the only risk is in failing to make the necessary trades whilst that price differential continues and before it closes. By contrast with this, the trader in goods must guess that goods produced at point A will be in higher demand when taken to point B, about which he/she could be wrong.

Accounts of the pricing anomalies typically exploited by arbitrage note only that securities are temporarily "mispriced". Mispricing does not imply that the price of securities has somehow deviated from a "true" price, which equates to its intrinsic value or worth. "Mispriced" is used in its minimal sense, to mean no more than that the mechanisms by which prices are derived provide a basis for anticipating a different (in this case an identical) price. The fact of "mispricing" (irrespective of any anticipated movement of the prices) nonetheless provides the basis for the creation of profitable returns. Thus the trading activity of an arbitrager anticipates the price movement and takes action that typically *closes* the mispricing. This indicates the possibility that the action of trading may itself have an impact on the outcome, which is a recurrent issue with the actions of hedge funds, as we shall see. Be that as it may, clearly, to be possible at all, successful financial arbitrage depends upon modern trading arrangements and, especially, highly efficient and well-programmed information technology. Although it is undertaken, the majority of hedge fund activities are not precisely in this classic form. What we see instead is what is called statistical arbitrage, which is by far the most significant contemporary form of arbitrage (Zubulake and Lee, 2011).

Statistical arbitrage is not typically arbitrage in its pure or riskless form (Bondarenko, 2003, p. 876). In statistical arbitrage, a price is assumed to be moving to an anticipated reference point, or in an anticipated direction. Here, the arbitrage opportunity is not primarily an empirically identified opportunity for gain arising from different prices existing at the same time, but only a probabilistic *potential* for it, which may be estimated in various ways. Strictly speaking, this then should be called "quasi-arbitrage". If the probability of an anticipated positive outcome – the movement of a price to an anticipated positive reference point – is calculated at greater than 50 per cent, then it is likely to be judged a movement from which gains can be

made. In addition, the larger the number of trades that can be made in the process of the price movement (and if the costs of trades are relatively small), then the greater the number of desired outcomes and thus the greater the potential for greater net gains (this is intrinsic to the law of large numbers). In its essentials, un-augmented and as described here, probabilistic statistical arbitrage is simply a sophisticated form of market trading. However, it is invariably accompanied by the addition of hedging practices, which are the leitmotif of hedge fund activities and which, theoretically at least, remove the possibility of loss in any market conditions.

Conventional investment strategy makes profit by going long. "Long" refers to buying equities or securities in order to realise returns from a putative increase in the value of the stock – it does not these days refer to the duration for which that stock is held. Classic hedging is taking out a form of insurance specifically designed for the purpose (usually a contract in a futures market) to ensure against possibility of loss if market movements are adverse against expectations. In its inception this practice merely minimised or mitigated losses from trading long. Since then, of course, various futures markets have emerged that trade investable futures securities in their own right. Alternatively to classic hedging, there is the possibility of making profit in a falling market from going "short" or "shorting". The basic principle here is simple and can be achieved using a variety of procedures (Culp and Heaton, 2008). Going short refers to the practice of gaining control of an equity or security (or sometimes simply making a credible claim to do so) in order to realise returns from anticipated falls in price. The short-seller contracts to sell an equity at a future date, the contract price of which is more than the market price the short-seller is anticipating at that date. The seller completes the contract with stock bought directly from the market at the later, lower market price. Alternatively, the short-seller borrows stock via a prime broker (typically holding the securities of a long investor), sells that stock or security at the current market price and then buys the equivalent amount of stock at the lower market price, which is then returned to the prime broker.

The essence of statistical arbitrage

In statistical arbitrage the basic principles are that if a stock or security is under-performing some reference point it is a candidate for a long position; if it is out-performing some reference point it is a candidate for shorting. The assumption is that the price of the equity or other security tends back to the reference point. If one thinks of this in terms of behaviour, one is assuming that there are collective irrationalities in markets that then correct. The irrationalities may arise in a variety of ways. However, there is the clear possibility that, given the scale of their activities, hedge funds can create a pattern of volatility and by their continued activity also tend to produce a recursion to an underlying regularity or consistency in pricing. However they arise, irrationalities take the form of an initial collective over-reaction – positive information causes short-term increases above the reference point, whilst negative information causes short-term decreases below the reference point. Recognising this psychology as a general tendency of the market provides the arbitrager with a reason to take a contrarian position. A return is made on the reversal from the over-reaction. A return is made on a shorted equity as its price falls back to the reference point, whilst a return is made on an equity held long as its price increases towards the reference point; recalling that the reference point is indicative of a longer-term underlying price.

If the basic concepts involved in statistical arbitrage are relatively simple, the tactics developed to apply these principles are far from being so. For example, amongst statistical arbitragers a popular strategy for investment decisions is termed "mean reversion". A hedge fund applying this technique is looking for what are termed "co-integrations" (Dunis and Ho, 2005, p. 36). A co-integration is in effect a longer-term regularity or consistency in the relationship between variables, i.e. how they move in terms of each other. One might be looking for a co-integration between pairs of equities or equities and the market index, or one might break down the market into sub-classifications. For example, one might break down the market into specific sectors (industrials, retail, banking and so forth), or classifications by market capitalisation, sub-categorised into deciles by size of corporation for instance. The key point is that individual equities are statistically analysed and grouped in ways that give a basis for anticipating price behaviour. The grouping will be based on a co-integration relation for short candidates and a co-integration relation for long candidates. A key component in the approach is the identification of the error-correction term (ECT). The ECT is the deviation from the reference point and thus the basis of the anticipated degree of reversion and profit. In mean reversion, as elsewhere, arbitragers rely on an over-reaction followed by a "correction". However, there is no certainty that the underlying regularity will persist either for individual equities or for markets in general. In any given period of real time some of the anticipated reversion may occur, or none at all[2]. If no reversion occurs within a period, then that period is one of "momentum", i.e. the persistence and growth of a deviation from a reference point. The result would then be losses for the arbitrager. Hedge funds seek to protect themselves from such losses in two ways[3].

First, the use of long and short positions creates a hedge (the classic practice associated with hedge funds). In its purest form this is termed "market-neutral". There are several ways of approaching market neutrality, but the easiest to understand is value or dollar neutrality[4]. If the initial position taken by the hedge fund contains an equal value of short and long equities, then if the market and the positions held in it moves in a direction as a whole (up or down) there will be losses on one side of the position and gains on the other. If the whole market rises then there are gains on the long but losses on the short. In principle, because of initial equal values, the gains offset the losses. The hedge fund's position is insulated from general market movements – it is 'neutral'[5]. The actual returns made by the hedge fund are based on the sum of correctly identified reversions, i.e. the positions held short that then fall and the positions held long that then rise, net of any equities that simply conform to the hedge.

Second, since the regularities that form the basis of mean reversion may fail to manifest for any given equity for any given period, a statistical arbitrage approach encourages the hedge fund to apply the approach to a broad portfolio of securities. In so far as mean reversion is a dominant theme within the market or an identified sub-set of the market, then a hedge fund trading in many equities can expect a net return if it trades a broad portfolio in relation to the identified co-integration. However, if returns derive only from correctly identified mean reversions and in any given period some reversions may not occur, then net returns can be relatively low. The hedge is preventing losses but it is also eating into potential profits. As such, though many hedge funds use long/short strategies as a hedge, few are fully market-neutral (Ineichen, 2002). Markets typically have a general trend of movement and funds can

potentially profit from this if they weight their investments towards that movement. As of 2009, Credit Suisse/Tremont Hedge Fund Index data indicates that only 1.7 per cent of hedge funds were designated as market-neutral, whilst 22.9 per cent were designated as following a long/short equity strategy (others operated in other markets); it has, in any case, often been observed that pure market neutrality is likely impossible in any real investment strategy (Patton, 2009)[6].

The key points, then, are that statistical arbitrage is based on the identification of underlying relations that persist into the future. Its potential profitability is based on correctly identifying statistical relations. The contingency of those relations means that returns can be relatively low and that there is a potential advantage to trading broad portfolios of many equities in relation to markets or significant sub-sets of them in which a co-integration is identified. Thereafter, though the general concepts involved in statistical arbitrage may be simple, the specifics that translate this into a profitable system in real and thus imperfect markets are considerable. The statistical arbitrager must adequately model long-run relationships of the market in order to identify the constituents of mean reversion. They must identify the dynamic error-correction relationship. They must generate a scoring formula that designates given stocks as under or over performers – providing a basis to select candidates to be held long and short. This then has to be applied. They must be able to generate a real-time trading system.

Statistical arbitrage: effects on securities markets and businesses

It is the inherent characteristics and tendencies of the trading system that make statistical arbitrage and hedge fund activity significant for corporations. The statistical arbitrager is, in the developed forms of the strategy, constructing a balanced portfolio. Returns are based on a combination of long and shorts. In order to realise returns the hedge fund frequently closes out its positions whilst dynamically reconstructing the portfolio balance in order to maintain (to some degree) market neutrality. Returns are based on the deviation from some putative underlying price relation. Conformity to this relation is contingent in real time, encouraging the hedge fund to trade in broad portfolios of many equities. Here, in essence the arbitrager is relying on averages in two ways. Prices return to an average, and in real time, on average, sufficient equities will conform to this behaviour for the strategy to be profitable. Profitability, for the statistical arbitrager is in effect about trading an identifiable pattern in the volatility of the market in a probabilistic way[7]. Identifying trading opportunities need then be no more than seeking a pattern as an observed statistical relationship. The relationship itself is held to be indicative of an underlying psychology of the market – over-reactions and correction.

Statistical arbitrage is thus a way to approach long-short strategies constructed across an entire portfolio by a hedge fund (Jacobs and Levy, 1993; Lo, 2008) and to make considerable profits over relatively short periods of time. Statistical arbitrage clearly also depends on high frequency trading (HFT) – considered more fully in the next section of this paper – which maximises returns on correctly anticipated market movements, and the frequency of very large trades is also a factor in realising high returns. Also, given that a hedge fund is, however, also very often a potent actor affecting markets simply by their engagement in trading activity, they may be identified as acting in ways that contribute to producing what are for them desired

outcomes. There is, obviously, a great deal of latitude here regarding what this notion of "contribute" may mean, but with this observation arrives the suspicion that hedge funds can create favourable trading conditions for themselves. Whether it is astute prediction of market trends or also hedge funds manipulating markets, statistical arbitrage is an area of hedge fund activity that has consistently grown in significance over the last two decades. There are some instances already identified, in which participation in markets by hedge funds has produced a market bubble, which when obvious, some of these same funds have then shorted, producing spectacular profits for themselves.

So, a hedge fund applying a statistical arbitrage strategy is creating profit on average based on a focus on the average (in terms of reversion). In so far as the approach is applied to broad portfolios of many equities, the statistical arbitrager is trading the market (or some significant sub-set of it) not trading in the market[8]. The individual corporation simply becomes a card in a mechanistic card counting system designed to exploit the mechanics of the securities exchange based on patterns. Furthermore, the statistical arbitrager is doing more than simply counting cards, he/she also has the capacity to affect the dynamics of the system in a way that a gambler in other environments cannot. Betting in a casino or on a horse may affect the odds but it does not materially affect the results (e.g. Smith and Williams, 2010). However, if an arbitrager takes a long position in an equity that is underperforming a reference point (or a short in an over-performer) then they are adding to the volume of trades that are counter to the current trend of the given equity, i.e. they are helping to fulfil their own expectations. One might say they are contrarian investors taking risk. But one might as easily say that they are making the market from which they are then profiting.

This last point is highly significant for the evolution of equity markets. If statistical arbitragers, each trading large portfolios and using a mean reversion approach, become the dominant traders on markets then many hedge funds following the same strategy would be seizing on the same volatility in approximately the same ways. As such, mean reversion would be the norm and, in so far as every hedge fund would be seizing on the same opportunities, they would be closing them more quickly (since the volume of trades countering the initial trend that was the source of the volatility would be greater at any point). As such, the time lines of profitability of arbitrage would reduce. So, not only does a statistical arbitrage approach involve potentially low returns because of the contingent nature of reversions, subject to hedging, but also the very process of engaging in arbitrage can reduce the returns on the strategy. But it does so because of the growth in the number of arbitragers trading large portfolios. The attraction of the approach and its relative success begin to change the dynamics of equity markets.

The contribution of high frequency trading (HFT)

In principle, neither arbitrage nor statistical arbitrage require high frequency trading (HFT). However, as may be intuitively appreciated, the expansion of statistical arbitrage has contributed to the attractions and growth of HFT.

Amongst other things, HTF greatly extends the potential earnings from the use of statistical arbitrage. As formalised and mechanised methods of trading have developed, arbitragers have shifted to larger portfolios and to shorter timelines of

trading. Computational developments and trading exchange infrastructure connections have facilitated this process. In the twenty-first century statistical arbitragers are in a position to apply their trading strategy via "black box" computerised systems "involving large numbers of securities (hundreds to thousands, depending on the amount of risk capital), and very short holding periods (measured in days to seconds)" (Khandani and Lo, 2007, p. 6).

These black box systems are a direct development of the real-time quotation systems introduced on the major exchanges in the 1980s. These, combined with communication technology, make it possible to develop trading algorithms, i.e. the execution of orders based on a set of parameters that can be coded into a computer. HFT qualitatively changes trading. The trader can be simply pursuing a more rapid form of mean reversion arbitrage, but they can also be evolving the trading practices based on the connectivity of trading systems and the relative speed at which they are able to intercede in the trading environment (Lallemand, 2012; Zubulake and Lee, 2011). HFT traders seek to locate their hardware at optimal locations in terms of particular exchanges or other newly developed trading platforms (the market making bodies through which securities flow). The exchange or platform then offers particular information access to the HFT traders – typically either a preview of the emerging order book (a "flash") or a direct feed of its order books as volumes of bids and offers are made.

The "collocation" (optimal proximate location) of the high frequency trader and connectivity of its hardware allows a "latency" between information arrival on the exchange and for the high frequency trader of as little as three milliseconds, trades can be processed in 500 microseconds (e.g. Wissner-Gross and Freer, 2010). HFT traders are then able to rapidly buy and sell into the order book as any given volume is distributed. Complex statistical models and derived algorithms are then used to engage in rapid-fire trading. There are numerous profitable potentials here (Lallemand, 2012, pp. 27-35). Though the return may be as little as $0.003 on the trade, the opportunities involved are perennial, and frequent large volume leveraged trading enables returns to accumulate.

Here, clearly, a form of financialisation is occurring. The securities exchange – in essence the market capitalisation of corporations that it embodies – becomes an arena for a kind of technological arms race. It does not follow that corporations experience collateral damage. However, a highly developed, market-based system of equity trading necessarily distances the investors from the businesses they buy into, but statistical arbitrage and high frequency trading transform this distance from one where the corporation is a unit dispassionately considered on its merits as a productive unit, where the profit potential is within the firm, to a situation where the individual corporation is not considered at all and any effect upon it is an unintended consequence of a totalised strategy that creates meta-profit potential from price movement beyond the level of the firm. Moreover the mechanics of statistical arbitrage and high frequency trading can create systemic vulnerabilities for corporations.

In statistical arbitrage and especially statistical arbitrage using HFT in particular, trading volumes – fairly obviously – cannot be considered as a proxy for investors' "confidence" in investment assets, as economists have hitherto taken to be fundamental to effective market functioning. This is a form of trading in equities that at best ignores the primary purpose of the market for equities. Both statistical

arbitrage and HFT are dominated by hedge funds (including hybrid independent proprietary firms) and the former investment banks. The market is, in effect, commandeered by traders extracting a return from aspects of its mechanism. As a result of what they do the volume of transactions hugely increases and so cannot work as processes primarily making signals about performance. This, then, is a form of extreme financialisation in action (Froud *et al.*, 2006; see also Fichtner, 2013). As we have argued, statistical arbitrage cannot be equated with HFT, but the dynamics of arbitrage using HTF have contributed to the tendency for market trading to become much more quantified and for the volume of trades to increase greatly. This then creates a complex of vulnerabilities in equity markets, which are an important aspect of the environment within which corporations operate.

Arbitrage armageddon?

Statistical arbitrage within high frequency trading is based on a causal complex with significant potential to damage corporations. Various scenarios are possible. One important one might be described as a stop-loss cascade. If there are many hedge funds engaged in statistical arbitrage, using broadly similar models, they will be identifying the same range of equities as under- and over-performers. They will be doing so using a portfolio construction that is based on all of the equities in an index or some significant subset. Now, consider a situation where the position on a given heavily weighted equity fails. All funds are likely to hold a significant position in that equity based on a market-neutral strategy. In one sense it may seem perverse that the positions can fail if many hedge funds are taking similar positions on the same equity that runs counter to the current trend (the convergent focus ought to significantly contribute to the mean reversion). But there may be many reasons for this failure:

- there may be cross-interference from derivatives trading (a new large futures position may be built creating implied pricing effects in the current market);
- a large fundamental stock picker, for example Buffett's Hathaway, may take a new position that augments a current trend;
- a whole host of new investors may converge on the market based on new information that maintains the current trend;
- something additional may occur outside the thin information the models are using to trade, for example an equity lock-in may expire enabling the original investors in a stock to flood the market;
- a major investor may be forced to sell into the market to realise cash in order to meet debt payments;
- a computer may malfunction or human error occur, etc.

The point is that the position fails and that position is a large one for the individual arbitrager and, because of the nature of the arbitrage system, it is replicated across mean conversion statistical arbitragers.

Now, consider what that failure might do. As the failure of the position develops, an individual automated arbitrage system will reach a stop-loss situation. At this point, the arbitrager unwinds their position – sells a long or closes out a short by seeking to buy up the equity before losses grow any more. This has various effects. It creates momentum for the trend in the given equity. Statistical arbitrage is based

predominantly on mean conversion. Additional momentum means that more arbitragers will hit their stop-loss, creating more automated reactions, creating more momentum. This may only continue until all the arbitragers have unwound their positions in that equity, in which case the effect may be a significant loss to the hedge funds and a significant augmentation for some period in the current trend in an equity, but may travel no further than that. The rate of travel in that given equity, however, can be shockingly quick since a great deal of trading is automated and second by second. Furthermore, if all the positions are large and the equity is heavily weighted in the index for the exchange then the index itself is also significantly affected. Selling long positions will cause the index to fall. This may be enough to cause selling either across the index or specifically in equities similar to that which began the cascade (which may occur anyway as each arbitrager seeks to rebalance their portfolio after closing out their position on a significant loss). In which case, the failure of one position may lead to the failure of several, each with an associated stop-loss cascade. Those stop-loss cascades, moreover, are not simply confined to high frequency traders, they also pass on to all the statistical arbitragers and long/short traders applying similar strategies but without high frequency systems. The cumulative effect is to transform short-term mean conversion volatility into an expanding ripple of market momentum. The market capitalisation of all corporations could thus be perversely affected by the failure of the mechanics of automated trading and the generalised nature of the strategies inhered in high frequency trading.

To state this starkly, a trading system that seeks to gain by exploiting the mechanics of the exchange can inadvertently cause the exchange to implode periodically. That failure, furthermore, may then also produce a market lock-step – if the majority of traders are trading the same shares in the same ways in the same time periods, and doing so in ways that confound mean reversion, the whole market can be erratic but correlated – shifting like a ship in a storm. Returns on long/short strategies and mean reversion statistical arbitrage in particular are based on the anticipation of underperformance and over-performance. Two characteristics will then cause returns to fail. First, the dispersion narrows or is eliminated. This effectively means that equities move more in lock-step with the market or its subset as expressed in the co-integration (all up or down and to the same degree). The more market-neutral the hedge fund strategy is the less its returns under these circumstances. Second, the market becomes entirely erratic – there is no clear basis (in fundamentals, general mathematical models, or technical analysis) from which to anticipate the under- or over-performance of equities. Markets, then, that are too aligned (an unwanted correlation) or too erratic (rather than simply volatile in a consistent way) or some combination of the two (since one could have low-dispersion erratic markets) reduce or eliminate the basis of returns for hedge funds based on a long/short strategy.

The point is that when statistical arbitrage fails it can produce a systemic effect that both perpetuates the problem of collapsing markets and perpetuates funds' own losses. This is an important point because one becomes used to thinking of hedge fund returns in equity markets as some form of alchemy – able to conjure returns out of any market conditions. This is not the case for long/short strategies. Returns are made on the basis of the exploitation of rules and tendencies – if the rules and tendencies are disrupted then so is the basis for returns. Even though statistical arbitrage typically trades within the day on an overall position and, within that in terms of positions that may

last seconds and sub-seconds, the disruption it creates can spread out over days or weeks. The impact can, however, also be spectacular and incredibly rapid because trading is on a second-by-second basis. In either case the impact is in part because the very existence of statistical arbitrage – and its replication – can change the nature of the equity market in which it trades.

The adverse effects, moreover, can be produced in a variety of ways. They can, for example, be produced by a more intimate relation between trading and debt – that then highlights profound weaknesses across the whole network of the finance system. As the number of mean reversion arbitragers increases, volatility prior to any failure of the system will tend to decrease, indicating that the rate of return on the arbitrage decreases. As we have noted, this creates an arms race situation. One aspect of this is the use of leverage, since debt allows larger volume trading on a smaller equity base, creating higher net returns. However, this hedge fund debt, typically provided through a prime broker by a banking syndicate, is collateralised and subject to margin calls. This means that the hedge fund must maintain a minimal threshold ratio between the value of the collateral against which the debt is secured and the value of the investments made with the debt. A fall in the value of either the collateral or the further investments results in a margin call – the ratio must be restored. The failure of a statistical arbitrage system creates losses for the hedge fund. These in turn create margin calls via the prime broker. The fund may then have to reduce its positions. Reducing its positions reduces its implied exposure in terms of the value of its collateral and also realises cash that can be directed to the prime broker. However, reducing positions means selling into the market; this produces the same dynamics as the previously described stop-loss cascade. The effect here can be more attritional, a series of cycles of margin calls and sales, ending in the failure of the hedge fund or some eventual accommodation with its bankers. The ripple of effects here also indicates something about the nature of market liquidity.

One of the standard arguments offered by proponents of hedge funds is that they provide liquidity to markets (Baker, 2011). Here, the point emphasised is that their constant willingness and capacity to trade creates a pool of buyers and sellers that keeps markets active – enabling them to be "efficient" in the technical sense of that term, as it is used in mainstream economics. The claim is made even though hedge funds might be applying technical analysis that requires behaviour that efficient market theory assumes does not exist (Bernstein, 2006). The claim, moreover, has serious limits as it relates to the role of hedge funds – even if one is a proponent of mainstream theories of "efficient markets". If arbitragers and HFT come to dominate the market, who is it they are offering liquidity to? Bear in mind that the Federal Reserve Bank of Chicago reported in 2010 that 70 per cent of the total volume of trading in US equities in 2009 was undertaken by 2 per cent of the trading firms in the USA and that trading was essentially HFT (Clark, 2010). Though it is important to differentiate trading volumes from the total value of the market capitalisation of listed equities – held by institutional investors – one must still acknowledge that the active market is increasingly dominated by a concentration of a few automated traders. This highlights a curious feature of the concept of mispricing and of correction.

Arbitrage functions by exploiting the statistical ramifications of anticipated collective irrationalities. At the same time, the profitability of statistical arbitrage causes it to grow and the internal dynamics of the return effects (essentially

diminishing returns) require it to also become faster and larger. But the strategy is necessarily assuming that the exploitable collective is part of a definable market beyond the arbitrager – not constituted by other arbitragers. In so far as the active market is increasingly dominated by arbitragers and high frequency trading the very notion that the market is being made and remade by the dominant sum of collective irrationalities of other investors (the rest of the market) becomes questionable. Here, the concept of a market "correction" becomes as curious as that of mispricing. It has a technical sense but seems to violate ordinary understanding of the term.

As arbitrage and HFT expand then the proportions of other investors who are active reduces. This raises a problem and a possible consequence. First, in the end what will equity prices signify if the trend continues? An active market consisting solely of statistical arbitragers and high frequency trading ultimately becomes a virtual construct whose prices will be dictated by an internally referenced statistical game of snap between computers whose threshold for this game of information exchange and pricing will be limited only by physics – essentially a Planck unit, at which point the system will have no return potentials and will have reached its own nadir – an ultimate general equilibrium (an autochthonous singularity). There is a basic technological fallacy of composition here – as many begin to do what one did, the opportunity that was open to one is not generalised but destroyed (a perverse form of equilibrium). The outcome is absurd, but also a logical potential, if unobstructed, built into statistical arbitrage as a technologically developmental systemic strategy. And, it is no more absurd than the notion that one can sell a mortgage to a person with neither assets nor a job because a mathematician says the system can afford to parcel that debt out.

More immediately, and more germane perhaps in terms of ripple effects, the capacity of statistical arbitrage hedge funds and high frequency trading to offer liquidity can disappear precisely when it is of most benefit to the finance system, to equity markets in particular, and to individual corporations listed on the exchange. Liquidity means entities provide both buys and sells. This becomes most significant at times of stress. When a market is collapsing, in general one's need is for counterparties able to buy into the market to prevent adverse averaging effects on all corporations, and to place a brake on the kind of panic that then becomes problems in credit insurance for supply chains, etc., that follow lines of contagion. But to be a significant source of liquidity that source must also be a significant proportion of the market. This is simply another way of stating that statistical arbitragers trade frequently and in large volumes, as we have noted in several different contexts previously. However, that trading is based on leverage, and in so far as arbitragers become active sellers to close positions – either because of initial momentum effects or because of margin calls directly – the arbitragers can then become one side (the negative) in the market and lack, in general thereafter because of losses (and the subsequent discipline imposed by prime brokers), the capacity to be buyers. The liquidity offered by statistical arbitragers is thus unstable and potentially asymmetric; and liable to disappear in situations where it is most needed. Hedge funds are pro-cyclical in their capacity to operate here, and not necessarily counter-cyclical in any beneficial sense.

Moreover, one must consider the nature of the liquidity that automated high frequency trading is actually supplying. HFT of the kind illustrated by Zubulake and Lee (2011) – extending into repeated buying and selling into an order book (a "stack" whose birth-death process potentially involves shifts back and forth between

automated traders) is a kind of illusion of liquidity; there is rapid movement but no actual progressive accumulation of an inventory of stock to match the trading. There is no genuine demand or supply here – the market mechanism is simply being simulated, at the same time as a return is extracted by the simulation. When something goes wrong, and the positions are unwound, they are not then necessarily replaced by more of this simulation, the automated trading can simply come to halt as the computers shut down. Real market liquidity is then revealed, and since automated traders have come to dominate trading that real market liquidity can be extremely thin, resulting in further perverse price effects within the general problems of either cascades or long-term market attrition. For example, as a series of sells feed into the market and are matched against buys, market orders are enacted. If there is no immediate buy side the sell may be placed on holding and apportioned a notional value (1 cent, as a "stub quote"), an automated trader, not programmed for this eventually may then execute the trade, selling at the notional value; because of what is essentially a programming failure revealed by the withdrawal of liquidity, a stock of a previously highly rated corporation can bounce to this notional value.

Much of this may seem like worst-case scenarios, and this is true. However, there are two initial responses here. First, these scenarios are a product of financial innovation. They are a consequence of the general problem in finance of the conflation of reality and modelling with practical consequences (a point eloquently made by the former Goldman Sachs quant; Derman, 2011). They are unintended consequences of financialisation and any potential benefits to corporations during periods of "normality" are essentially unintended and highly conditional. The innovations have been primarily focused on the aim of profiting from the innovation rather than from serving corporations. The order of priority here seems wrong. Second, the possible has happened, and variations are likely to occur again, despite the existence of technical solutions for some specific problems. This is important not only because we do not live in "normal" times but because the basic changes to the finance system that occur during "normal" create the conditions we then live in – there is no sharp divide between normal and abnormal, where the financial innovation becomes justifiable simply on the basis that any given crisis is over.

The possible has happened

The first week of August 2007 is now recognised as the trigger point for the global credit crunch that then developed into the financial crisis of September 2008. The events of August typically focussed on are the sudden collapse of two of Bear Stearns' funds that were heavily invested in mortgage-backed collateralised debt obligations (CDOs). However, during the same week long/short and equity market neutral hedge funds also suffered significant losses (Khandani and Lo, 2007). By 2007 the TASS database reported a combined 600 funds operating overlapping strategies in equity markets and with a total of $160bn of assets under management. From 7 August until 9 August, US stocks experienced movements away from market averages, based on a breakdown of those stocks into deciles of market capitalisation. On 7 August, based on an estimate of 8:1 leverage, a basic statistical arbitrage position within the S&P would have lost 4.64 per cent followed by a further 11.33 per cent on 8 August and 11.43 per cent on 9 August – generating a cumulative loss of 25 per cent, sufficient to wipe out poorly capitalised funds and enough to cause others to deleverage. Khandani and Lo

(2007) match this to reports by prominent and successful funds, which one might anticipate were not as badly affected. These too experienced significant reductions (against historical reporting of significant returns): Renaissance, for example, reported an initial August reduction of 8.7 per cent (against typical annual reporting of a 30-40 per cent return on capital net of fees) and Highbridge Statistical Opportunities Fund a loss of 18 per cent. What is interesting about the sudden losses is that they were not caused by dislocations in the equity market but by the likely unwinding of a large unnamed fund in some other sector causing it to make debt distress sales of assets that then triggered the failure of a large position commonly held by many statistical arbitragers within the equity markets. Overall, the S&P actually initially increased during the period, though it did so in what was effectively becoming a bear market context (markets fell erratically throughout the year and began a series of episodic collapses on 21 January 2008).

Khandani and Lo (2007) make the point that the kind of regularities that statistical arbitrage relies upon are not necessarily brought into question by the sudden failure of the model during the week in August 2007. They do, however, also note that the source of the failure – the role of leverage and the connectivity of different funds inside and outside any given market – creates new avenues for systemic risk based on contagion, and this is difficult to identify precisely because of the non-transparent nature of the funds (see also Chan *et al.*, 2006). This, however, raises the issue of the causal complexity created by leverage and debt. A key issue here is collateral. As Lysandrou (2012) indicates, there is no clear-cut distinction between hedge funds operating in different strategies because they have common demands for forms of acceptable collateral that can be offered to prime brokers. These forms of collateral can be problematic in themselves and then problematic in any given attempt to subsequently deleverage. Hedge funds typically use AAA-rated fixed income assets as forms of collateral. As the number of hedge funds and the scales of their operation increased over the first decade of the millennium the demand for these kinds of assets found a ready source of rapidly expanding supply in mortgage-backed collateralised debt obligations. Lysandrou (2012) calculates that hedge funds held about 47 per cent of all CDOs in 2006. Once it became clear in 2007 that US housing markets were turning and that the basis of the construction of the CDOs contained basic vulnerabilities (see Morgan and Negru, 2012) then CDOs stopped being an acceptable source of collateral to prime brokers and hedge fund demand tailed off. Hedge funds thus both helped to create the conditions of the financial crisis and to trigger it; despite that they have been considered peripheral figures by many subsequent official investigations (e.g. Committee on Oversight and Government Reform, 2008).

The above may seem only partially relevant to the specifics of hedge funds activity in equity markets, but it is not. The connectivity of hedge funds, their flexibility and secrecy, and their use of leverage, create avenues of contagion, which make the specific operations of hedge funds in any given sector in which they operate vulnerable to the impacts of other areas in which funds operate. Khandani and Lo's (2007) argument is best read in this light. Statistical arbitrage can always be subject to failure because of the way hedge funds operate within the finance system (there can be sudden sell-offs, etc., triggered by obligations elsewhere). Thereafter, the specific mechanics of statistical arbitrage become problematic in particular, not least because of the expansion in the number of arbitragers taking common positions and because of the

increasing use of high frequency trading. Though Khandani and Lo (2007) are correct to point out that hedge funds went on to recover for a period after the events of August 2007, 2008 was a year of record losses for hedge funds, and for quantitative statistical arbitragers and long/short in particular. The most significant period of loss came after September 2008, but funds experienced losses throughout the year. In 2008 hedge fund reported returns were an average negative 19.07 per cent, with long/short market-neutral the worst performers, losing 40.3 per cent on invested capital (Low, 2009, pp. 1-2). The commonly identified problem by hedge fund commentators was one that has essentially continued thereafter, though to differing degrees: erratic markets with low dispersion – a breakdown in the underlying regularities that statistical arbitrage exploits (e.g. Harris, 2010; The Economist, 2011). That breakdown, it is important to bear in mind, is not simply a problem for the hedge funds. Since their positions are based on the assumed relations that then have failed, the failure results in unwinds that perpetuate the erratic movements in the market.

Traders can compensate by moving over to other strategies and governments can inadvertently compensate by creating new sources of liquidity through low interest rates and bank injections – which create capital that can flow into equity markets (a commonly identified trend in equity markets in 2009), but this introduces new sources of instability and has perhaps contributed to erratic markets. There then also remains a continued vulnerability to high frequency system failures. The most spectacular instance of this was the "Flash Crash" of 6 May 2010. The Flash Crash did not just occur on a single exchange but rather occurred across US capital markets. During a key 15-minute period for example, the Dow Jones Fell by almost 700 points and, within the day, fell by a historically unprecedented 998.5 points before rebounding (to a fall on the day of 3.2 per cent). Most shares fell in line with the market, but around 15 per cent experienced further perverse effects. Shares in Accenture, for example, fell by over 99 per cent from $40 to 1 cent, notionally reducing its market capitalisation from a prior typical $26bn to $6.37m (see Phillips, 2010). Shares in Sotheby's, by contrast, rose from $34 to $99,999.99 (Haldane, 2011, p. 2). At one point over $1 trillion was wiped off the market capitalisation of listed securities. Though capital markets recovered most of the loss quite quickly, prices did not fully recover to their pre-crash levels for two months. The crash has also been followed by a number of mini-crashes, both in equities and in commodities and futures markets (Cui and Lauricella, 2011).

Subsequent analysis has followed various lines of argument regarding the actual trigger for the crash (see Easley *et al.*, 2011; Commodity Futures Trading Commission and Securities and Exchange Commission, 2010). However, the common constituent of the analyses has been that stop-loss cascades and sudden liquidity withdrawals based on the dynamic interaction of high frequency trading played a central role in the events that then occurred. Regulators themselves remain unconvinced that they are in a position to resolve the problems of connectivity and complexity that now exist (Leinweber, 2011). The main focus so far has been on limiting the extent of effects. Circuit breakers already existed for given markets (a circuit breaker halts trading when prices range beyond a threshold – breaking trades and creating pauses), but the NYSE general threshold was 10 per cent (under Rule 80B) for the whole market (the collapse in the Dow as a whole never exceeded 9.2 per cent). Subsequent moves have targeted the thresholds on individual securities rather than merely the whole market and focused on narrowed time periods (e.g. Serritella, 2010). There has, however, been no

concerted move to confront the problem of mass arbitrage components in the market or of high frequency trading as a technological constituent of the market (operating beyond it in its liquidity function). Science and ignorance are combined in terms of the emergent properties of high speed trading. A recent article in *Wired Science* makes this clear (Klein, 2012). HFT enables sub-950 millisecond trading and that trading necessarily sacrifices diversity for speed, creating further homogeneity of action in computerised trading but also creating unexpected outcomes because of the interactions. New chips designed specifically for HFT can prepare trades in 0.000000074 seconds. As one researcher on the technology of trading notes:

> Economic theory has always lagged behind economic reality, but now the speed of technological change is widening the gap at an exponential rate. The scary result of this is that we now live in a world dominated by a global financial market of which we have virtually no sound theoretical understanding (quoted in Klein, 2012).

Circuit breakers notwithstanding, markets remain vulnerable to both continued mini-crashes and also the broader systemic issues generated by the expansion of quantitative trading, based on common strategies and leverage.

Conclusion

Hedge fund activity in equity markets is both a clear instance of financialisation and an ongoing source of vulnerability for markets and for the specific corporations listed on those markets. This, of course, does not mean hedge funds always and everywhere fail to make profits out of their trading or that they cannot have beneficial effects under particular descriptions (see Baker, 2011). If hedge funds persistently failed to make money then the funds would simply die off. If they created permanent crisis (within which they were visible) then the call for tighter control of their practices would be sharper.

The problem is really one of context and complacency. This is best posed in terms of the question: is there anything sufficiently beneficial about the activity of hedge funds here that makes it worth risking adverse consequences for corporations? This is a question with no short or single answer. However, if we resist thinking of corporations as financialised entities and think of them as productive units that carry the economic obligations of societies expressed through labour, then from this perspective hedge funds have proved on balance more of a problem than a benefit.

Hedge funds are active elements of a pathologically functional finance system. As interest rates fell during the early part of the last decade, many institutional investors, including pension funds, began to channel capital to hedge funds, seeking higher returns. Compared to the tens of trillions of dollars of capital held collectively by institutional investors the sums were small. The effect on hedge funds, however, was significant. By 2010 estimates of institutional investors' contribution to hedge funds ranged from 50 per cent (Maslakovic, 2011, p. 4) to 61 per cent (Preqin, 2011, p. 3) of hedge funds total capital, and that assets under management had increased from $456bn in 1999 to around $2 trillion (falling to a low of $1.33 trillion in the first quarter of 2009) as of 2011. If we accept that hedge funds have played a key role in the pathologies of the finance system that have resulted in the financial crisis and its aftermath, then institutional investors, including pension funds, have helped to build and then trigger that crisis for the sake of returns on just $1 trillion in capital (in relation to around $90 trillion of institutional capital).

This is by no means to place the full burden of blame for the current situation on any given actor. The point is rather to highlight the pathologies of the system and the ultimate consequences of those pathologies. As the Bank of England *Trends in Lending* report (April 2012) notes, the commercial banks have responded perfectly rationally to the crisis in individual terms by restricting lending to business (falling 3 per cent in 2011 on the back of declines beginning in 2009). In the UK and the USA, large corporations have also responded perfectly rationally to uncertain credit markets created by banks individually rational positions. In the context of fears over economic instability they are hoarding cash and limiting investment. Employment has thus suffered, and this has been further exacerbated by austerity measures imposed by most Western states in order to maintain their standing in credit markets as they seek to deal with the debt burdens that have been created by a decade long credit binge and the specific policies required to stabilise the finance system. At the end of 2011, GDP in the UK was still 4.1 per cent below its pre-crisis peak. The problems here have then fed back into pension funds. Equity returns have been poor, reducing the capacity of funds to meet their obligations at the same time as quantitative easing and low interest rates have reduced the value of gilt yields used to value the future liabilities of funds, raising the implied liability at the same time as the value of invested capital has fallen. As a result, the long-term problems of employment-based pension funds have been exacerbated by the economic conditions that institutional investment policies helped to create by diversifying into alternative investments like hedge funds. According to the Pension Protection Fund, the collective deficit in the UK's defined benefit pension funds (around 7,000), stood at £206 billion at the end of the first quarter of 2012. A social contract involving corporations is being broken on many fronts, and the broader significance of hedge funds is that they are part of the dynamics of this fracture. This is becoming a defining feature of financialisation as it evolves.

Notes

1. The relative rise in hedge fund activity correlates with the fall in individual investor direct holdings in equities – though is not the only reason for this fall. According to Capita registrars in December 2008 the percentage of individual small investors with direct holdings of UK shares fell to 9.6 per cent of the market (£118bn by value) – the lowest in modern history; the average total was 40 per cent for the 1960s and 20 per cent in the 1990s.
2. The theoretical basis of co-integration is based on a long-term that effectively becomes infinity. Real markets do not exist in infinity and real trading does not occur on the basis of infinity.
3. The following protections would not, however, prevent losses if momentum pushes long positions down and shorts up.
4. Neutrality can be measured in three ways: value-neutrality (e.g. dollar neutrality), sector neutrality, and beta neutrality. Beta measures the average movement of a market. Equity with a beta value of 1 moves in synchronicity with the market. Beta neutrality thus means rendering equity's beta 0. In theory this is achieved by trading on the reverse of the beta; specifically, one shorts equity by the equivalent of its beta. American Century Equity Market-Neutral Fund (ALHIX) reports as dollar neutral; JP Morgan Research Market-Neutral (JPMNX) reports as beta-neutral.
5. The use of financial instruments such as derivatives adds further complexity to this process but the basic principles remain the same.

6. In long/short pair matching or proportion matching strategies there are no perfectly matched pairs, even within the same industry; the active management of the positions is also unlikely to maintain dollar or beta neutrality (Michaud, 1994, p. 79). Patton (2009, p. 2525) finds that around 25 per cent of 1,423 hedge funds that had claimed to operate a market-neutral strategy using data 1993-2003 were "significantly non-neutral". HFR, however, defines market-neutrality (Hedge Fund Research, 2011c, p. 4) with the proviso that funds may have up to 10 per cent net exposure long or short. Variations in recognised characteristics mean that there are also variations in the reported database numbers of funds categorised as market-neutral.
7. This can be mathematically quite complex since the arbitrager need not simply expect some proportion of the portfolio to generate returns through a contingent conformity to the mean reversion process; he/she can also develop probability calculations of that conformity based on historical data.
8. Assuming that long/short continues to develop from simple matched pairs towards groupings as the capacity to do this is enhanced by computers.

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Dr Jamie Morgan works at the Business School, Leeds Metropolitan University in the UK. Over the last decade, Jamie has published in a range of fields – not only economics (in which he was initially trained), but also in political economy, organisation studies, philosophy, sociology and international politics. His current research interests include vulnerability in complex systems (applied to hedge funds and private equity finance), the critical failures of economics theories in institutions, and the development dynamics of the People's Republic of China and India. He co-edits *Real World Economics Review* (with Edward Fullbrook). *RWER* is the world's largest open-source economics journal with over 20,000 subscribers and an average of over one million article downloads per year. He is the Secretary of the Association for Heterodox Economists, a main proponent of the movement for new economic thinking. Jamie Morgan can be contacted at: j.a.morgan@leedsmet.ac.uk

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