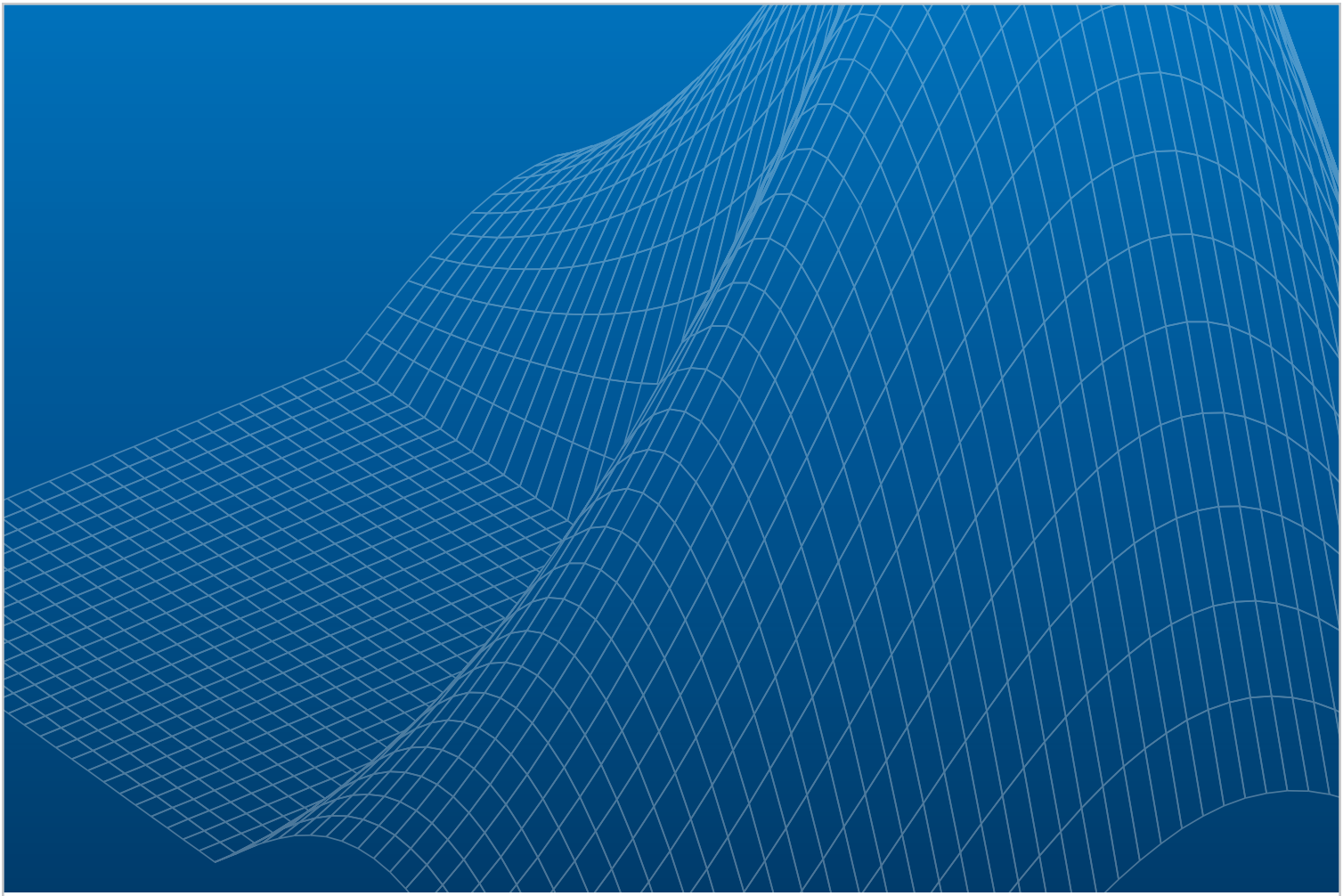

Modelling and Analysis in the wake of the Global Financial Crisis: The Financial Services Perspective

MathWorks®

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State of the industry overview

The second largest outlay for the average financial institution is its data – second only to the cost of staff. Data is used across the organisation, most commonly and potentially profitably in trading strategies, but it also supports every other function, including risk management.

The 'data deluge' has captured the interest of the media worldwide, as industries seek to capitalise on the data that exists in their own organisations and in the public domain. However this is not a new phenomenon for financial services, which has sought techniques to monetise data for decades. Today's challenge is dealing with the 'three Vs of data' – volume, velocity and variety.

Unprecedented levels of regulation are facing the industry, post-2008, including MiFID II, UCITS, Basel III and Dodd-Frank. However it is apparent from our research that while firms are adapting to adhere to regulation, this is not a key driver in model production or model use. In fact, businesses commonly hold the view that instead of dedicating resources to risk models to appease regulators, this would be better allocated to bring alpha generating models into production.

Against this backdrop, MathWorks has sought to obtain industry insights and opinions from within the financial services industry to better understand the importance that models and data have in all aspects of the trade lifecycle.

This in-depth study involved questioning 43 experts from within the buy- and sell-sides, as well as academia, including hedge funds, institutional investors, banks (including proprietary trading desks), broker/dealers and university lecturers. On the sell-side, four of the top 10 investment banks participated in the study[1].

In this report, we have tried to shed light on some of the challenges facing the buy- and sell-sides, and understand the key business drivers for popular data analysis and modelling techniques.

We hope you will find it an interesting read.

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[1] *Financial Times: Investment Banking Review, H1 2012, http://markets.ft.com/investmentBanking/tablesAndTrends.asp*

Analyst viewpoint

Keeping ahead of the markets

The financial crisis and the resulting crackdown on the financial services industry have made clear the importance of data and the reliability of that data to both the regulatory community and the market at large. Being able to rely on the quality of the data a firm is dependent upon to stay in business—reference data, historic market data, tick data, derived data and statistics, positions, and transactions, etc.—has never been more important. The same level of scrutiny is also being applied to models and processes underlying vital functions such as risk management.

Regulators are keen to increase data transparency to an unprecedented level across markets, including the more opaque world of OTC, by requiring higher levels of data granularity for reporting purposes and audit trails for that data. Reporting to trade repositories, adopting new data standards and aggregating data from across desks and lines of business for systemic risk reporting have all played into this dynamic. This is all with the intent of ensuring that firms are able to stand behind their mission critical processes such as risk and pricing calculations with some degree of confidence, because the alternative is serious reputational damage and lost business (and there have been numerous instances over recent years to serve as a warning).

Retaining a competitive edge in the current market environment is also no easy task, given the barrage of new regulatory requirements all driving at this increased transparency and the introduction of new market infrastructures and related processes that are hitting firms' bottom lines. For example, IT build-out for the support of clearing in the OTC derivatives space will be very expensive, especially for buy-side firms that have little of that infrastructure already in place. Hence getting a better handle on data and dealing with these new moving parts is of vital importance when attempting to keep ahead of the rest of the market and to retain a competitive edge.

Ad hoc processes and tools are no longer acceptable in regulators' eyes, especially within the walls of a potentially systemically important financial institution. The new regulatory mantra around the establishment of robust "systems and controls" also makes some degree of business sense in the long-term, even if it will be painful to get there in the short-term. After all, access to more reliable and timely data should, logically, result in better decision-making and risk management.

It is no simple task to cope with the incoming alphabet soup of regulation and the increased levels of data transparency required therein, but there are opportunities to improve processes, resulting in better informed and responsive trading and risk management teams in the long run.

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1.0 Key Findings at a Glance

Business outcomes

- 88% of financial institutions believe they would lose their competitive edge, 79% believe their profits would decrease, and 54% believe risk would be increased, if they were operating poor models – for example, flawed or outdated models
- Slow model development will result in firms lacking the agility to respond to market changes, and ineffective risk management , say 82% and 74% of firms, respectively

Model integration

- Cost (65%) and risk (62%) are the biggest concerns of integrating models into business processes
- It is currently taking 'months' (51%) to integrate models into business processes. However, the buy-side would like to cut this down to 'days' (75%); the sell-side ambitiously wants to reduce this time to mere 'hours' (40%)
- 83% of financial institutions are trying to speed up the process of model development

Trading strategy

- Quality of data (67%), smart models (54%), and speed of execution (50%) are the most critical elements of a successful trading strategy
- 59% of financial institutions are looking to increase levels of automated trading; 67% of sell-side and 46% of buy-side firms are looking to increase levels of automated trading
- Only buy-side respondents believe automated trading models have had their day, and 31% of buy-side firms are looking to move towards alternative trading models
- 54% of financial institutions are looking to improve the execution times of models

The data deluge

- The biggest issue associated with the data deluge is data quality, with 68% of respondents citing it as a challenge. Creating effective models (57%) and data variety (38%) were also among the main three issues facing financial services
- The actual volume of data is not a core challenge for financial institutions, with only 32% citing it as problematic
- The datasets being dealt with are, in general, not as large as externally perceived: 49% of financial institutions are dealing with datasets in gigabytes; 28% with megabytes
- The sell-side is grappling with larger datasets than the buy-side, as 19% of sell-side is handling datasets of terabytes

2.0 Introduction to models

When considering the major themes within this report including the data deluge, rapid business analytics implementation, and risk, it is important to situate where models help. Models can help analyse and mine large datasets to make them usable and consistent. Techniques such as classical discriminant analysis and machine learning inform bagged decision trees, while neural networks can classify data to help make sense of the data deluge. At the same time, optimisation methods help determine so-called maxima and minima, points of greatest opportunity and/or risk. Other model techniques are important for risk evaluation and scenario testing, e.g. Monte Carlo methods, perhaps as part of an expected shortfall regime.

In trading, strategies might use deterministic and/or probabilistic regression-based methods such as co-integration, or perhaps machine learning methods such as evolutionary learning or neural networks. The former are consistent, trend-based (historically simplified) and traceable, while the latter might be historically accurate but potentially inconsistent and inflexible when projecting.

In some cases, models benefit from being transparent, open, and readable – for risk, where regulators might communicate and collaborate with financial service firms there is a need for transparency. In other IP-contingent situations, for example buy-side trading strategies, model protection is helpful.

3.0 Impact of models on financial services – The bird's eye view

Models are vital to financial institutions' success

If data is the 'lifeblood' of financial services, financial models are the heart, pumping the data

Data is often referred to as the 'lifeblood' of financial services. But what use is data if it is not put to work, if it cannot be manipulated to tell us something? Analysing and modelling data takes a stream of ones and zeroes, and commercialises it into valuable information for a business. A trading model will pinpoint inefficiency in the market, for example, which financial institutions will be able to capture.

It is widely believed that banks and buy-side firms are dealing with data volumes several orders of magnitude larger than the 'big data' other industries are grappling with. While it is true that financial services companies are inundated with data, the datasets themselves tend to be analysed in gigabyte or megabyte size sets – not larger. However, it is in aggregate, that the data volumes are substantial.

Financial services are recognised by independent studies to be ahead of other industries with the maturity of their data analysis and modelling techniques, and they have come to rely on good models to maintain market leadership. However, pockets of financial services are just beginning to understand and capitalise on data modelling and its commercial benefits.

> *"We're improving and adding new models, to drive profit and attract investors – ultimately to grow the business" – hedge fund manager.*

Poor models would result in the loss of competitive edge and decrease in profits

According to the research, 88% of financial institutions believe they would lose their competitive edge, and 79% believe their profits would decrease if they were operating poor models.

> *"Cost and reputation risk are on the line for the bank when there is a mistake in a model" – tier one sell-side bank.*

Only 54% of financial institutions believe that risk management will be impacted by poor models. This is perhaps a surprising result, but could indicate scepticism among the quantitative analysts and engineers regarding the merits and applicability of current risk models. Other findings in this research indicate that respondents see building good process within financial institutions as a more effective antidote to bad risk management, rather than working on the models themselves. However, this is worthy of further investigation.

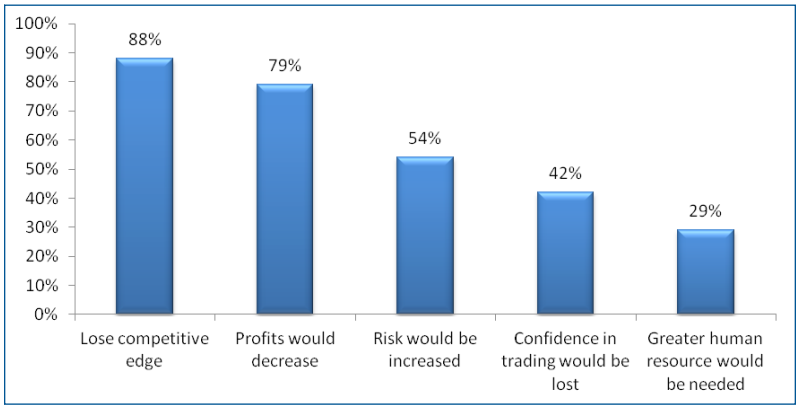

Fig. 1, What would be the impact to your business of poor models?

Risk and financial losses usually go hand-in-hand. If a product is mis-hedged for example, the risk exposure will be high and potentially more losses incurred.

The role of models in risk management has come under the spotlight recently following the extensive media coverage of multi-billion dollar trading blunders, which were supposedly the result of ineffective value-at-risk (VAR) models. Attitudes towards VAR as a valuable technique were fairly negative among research participants. Over-simplification of assumptions was one perception of VAR.

One wealth manager at a tier one investment bank said, "VAR is meaningless when interrogating such small amounts of data." While a hedge fund manager commented, "VAR is unreliable, but we use it as it's the most common and recognised model."

Several firms stated that expected shortfall is the model they're moving to from VAR.

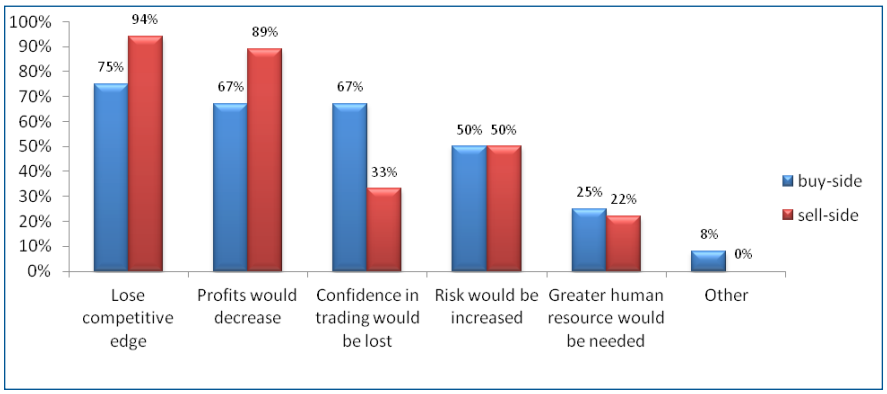

Fig. 2, The buy-side / sell-side split: What would be the impact to your business of poor models?

The sell-side is more concerned with the monetary and competitive challenges they would face as a result of poor models, with 94% citing that they would lose their competitive edge and 89% stating that they would incur a decrease in profits. The buy-side's responses were more evenly balanced across these factors, but they would also lose confidence in trading (67%). The buy-side is particularly atune to the benefits of good models in attracting investors, and the risk to their business of poor models, as customers would lose faith in the firm's ability to invest well.

> *"We have encouraged transparency with clients, since 2008. If we showed a poor model to a client, they may well choose not to trade" – tier one investment bank*

Financial institutions with slow model development are less agile, and have ineffective risk management

82% of financial services firms believe that they lack the agility to respond to market changes as a direct result of slow model development. As trading opportunities arise, firms need to move rapidly to develop models, to test them, approve them, and ultimately integrate strategies and analytics. Slow integration of models can result in diminished profits, as time-sensitive models can be redundant by the time they reach production, and the opportunity window may have closed.

> *"If the quality of the marketplace changes, for example if there is an increase in algorithmic trading, liquidity will change across the board. We will need different models to capture this" – tier one investment bank.*

As new trading venues come online, models will need to be validated to ensure they function correctly with the data coming from the venue.

Slow model development will also give rise to ineffective risk management, according to 74% of respondents. At some financial institutions, it takes months for models to be approved, meaning that the firm could be exposed to greater risk in the meantime.

> *"I need total confidence in the methodology of the model. The results need to be representative of the strategy" – tier one sell-side bank.*

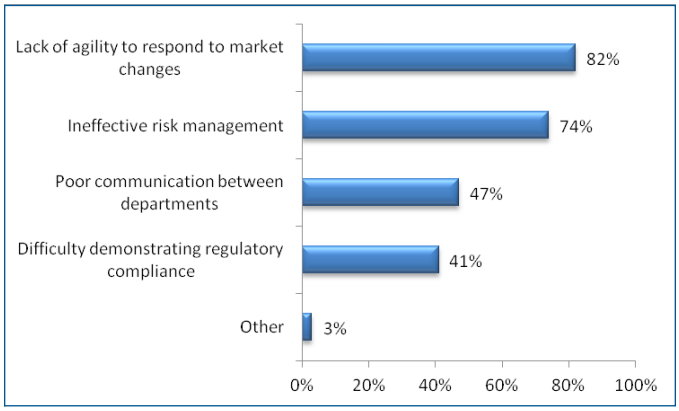

Fig. 3, What is the opportunity cost to your business of slow model development?

Model complexity – a complex matter

> *"All simple models and strategies which could have been done, have been done" was the statement of one sell-side banking respondent in a proprietary trading role.*

Financial institutions are taking different approaches to model complexity, with a fairly even split of those looking to increase model complexity in order to increase accuracy (53%) and those looking to reduce model complexity in order to make the results easier to interpret (47%).

Another sell-side banker stated that within his firm, "the retail side of the business is looking to reduce model complexity, while the institutional side is increasing model complexity to increase accuracy."

When we compare the buy- and sell-sides attitudes towards model complexity, there is an interesting imbalance. The sell-side is fairly evenly split between both attitudes. However the buy-side is leaning towards increasing model complexity, in order to increase accuracy. The buy-side is also moving in the direction of alternative trading models (see figure 13), which combined with an emphasis on complexity signifies that the buy-side is moving towards bespoke, human-driven trading models.

The sell-side is still coming out of 'crisis mode,' post-global financial crisis – it is focusing on executing the simple things well, such as risk management. In contrast, the buy-side needs to demonstrate intuition and competitive edge. Keen to demonstrate value to customers, the buy-side is incorporating more complex models and trading strategies in a bid to add more value, which can be seen in figure 4, with 73% of the buy-side looking to increase model complexity to increase accuracy. This can result, however, in reduced automation.

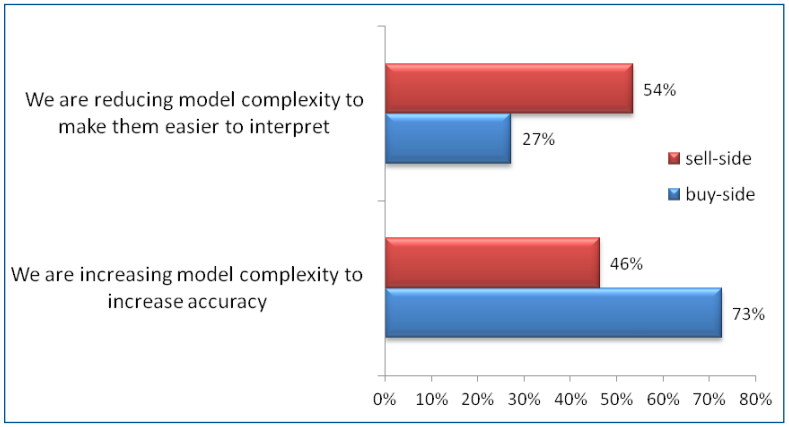

Fig. 4, The buy-side / sell-side split: Approaches to model complexity

How models are used in financial services

Banks use a variety of analysis and modelling techniques. Time-series (77%), regression (72%), optimisation (70%), and Monte Carlo (70%) are the most commonly used models by the respondents in this survey. Such techniques are common across the financial services industry, but different in application depending on what is being modelled, e.g. instrument classes, risk factors, trading strategies, and where it is being modelled, whether on the buy-side, sell-side or elsewhere.

Respondents recognise that models need to be practical, performing well against a defined benchmark and/or offering a realistic assurance of an outcome. However, the challenge is that models must have good assumptions. One explanation of the credit crunch was the over reliance on the Gaussian copula as an assumption for credit derivative modelling. This assumed that participants would act independently rather than uniformly as part of a 'herd mentality.'

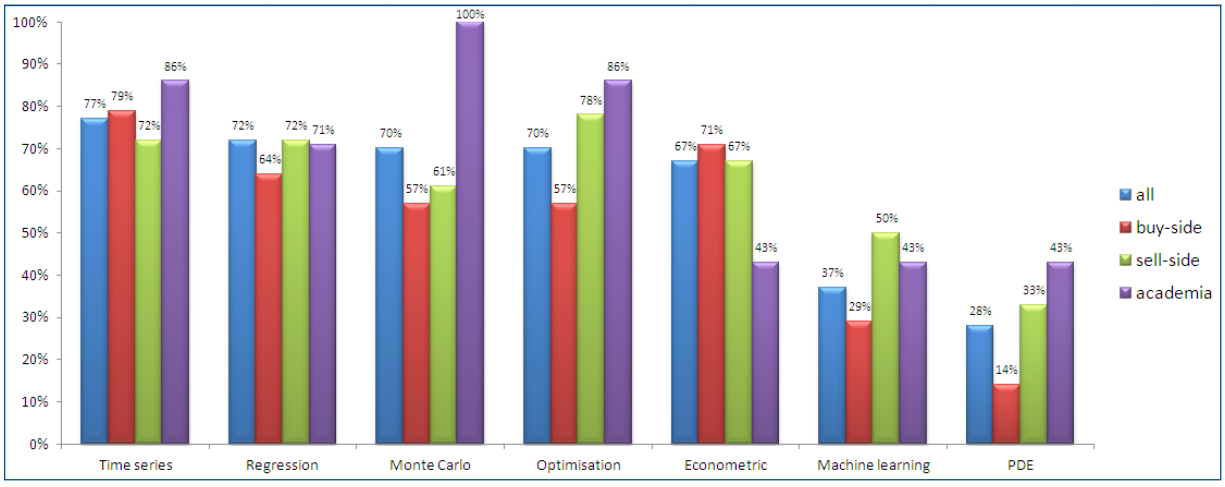

Fig. 5, What mathematical and statistical techniques does your organisation currently use?

Machine learning – polar reactions

The modelling technique which receives the most extreme reactions is machine learning. Across financial services, it is not as commonly used as time series or regression. However, several of the world's largest tier one banks are currently investing in new machine learning models, as it can extract powerful information from their data sets. When informed of the general industry concerns about the technique, institutions were keen to maintain focus on them to differentiate from their competition.

Due to the huge volumes of data that financial institutions deal with, machine learning is a suitable technique for trading strategy development, for classification of risk factors or stocks in risk management and investment analysis, and in fraud detection. While regulators and management can be nervous about applying 'black box' algorithms in risk management, some risk and actuarial practitioners are evaluating 'behavioural finance' machine learning methods. They are looking at this approach as a means to integrate human behaviour with statistical risk models, helping to balance qualitative aspects of risk analysis with quantitative.

Academically-taught models penetrate the 'real world'

The financial services industry and academia are not working in isolation. There is a very strong correlation between the data models being deployed within financial institutions, and the modelling techniques being taught at universities. Machine learning's most passionate advocates were those who learned the technique at university.

Quants and developers choose to work with the tools that they are most familiar with. However this will inevitably create a bias towards working with existing practices rather than striving for innovation.

> *"I want to use bleeding edge models. Outside-the-box ideas come from academics" – proprietary trader at tier one institution.*

Published academic research is the most commonly referred to source for new models, followed by the skills of new hires. It is common for a firm to adapt its models based on the skill set of employees.

4.0 Integrating models into live business processes

It is taking financial institutions months to integrate models into business processes

On average, it is taking months for financial institutions to integrate new models into business processes. This time period takes into account model conception, testing, and approvals. Slow integration will result in firms lacking the agility to respond to market changes (82%) and ineffective risk management (74%) – see Fig 3.

Sell-side respondents were emphatic that it's the bureaucracy within the firm that is slowing this process down. However respondents from proprietary trading desks suggested the lack of bureaucracy and approvals channels means they can have models live within hours, one reason proprietary trading desks are under close media and regulatory scrutiny. As a result of the Volcker Rule, under Dodd-Frank, it is proposed that proprietary trading desks are outcast from the US completely. Bureaucracy is less of an issue for the buy-side, as organisations tend to be smaller and flatter in structure.

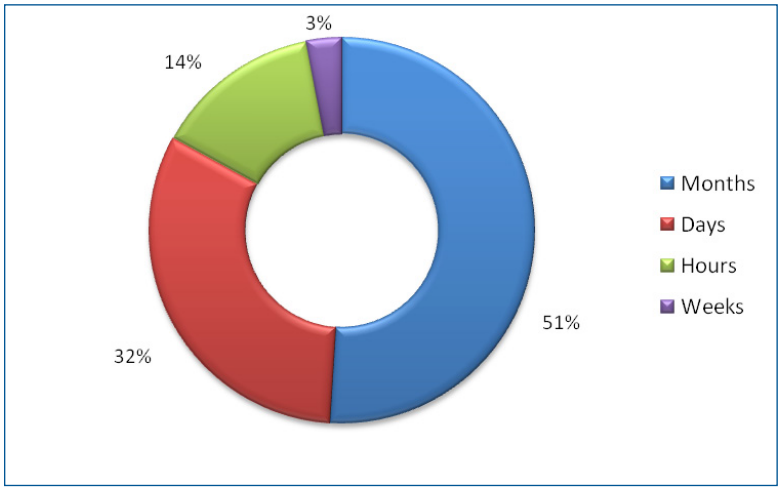

Fig. 6, How long does it currently take to integrate new models into business processes?

Speed is everything

> *"The bank's sales people want the models now. We need to reduce the development process from weeks to days" – tier one sell-side bank.*

Financial institutions across the board are looking to reduce the time to market for new models – 83% of those surveyed are trying to speed up the process of model development. It is clear from this research that models are relied upon for both risk management and alpha generation, and it follows that accelerating the process of model development is a key concern for all financial institutions. Shaving hours, days, or weeks off model integration could deliver a competitive advantage when an institution wants to capitalise on a market opportunity.

> *"It doesn't make sense to add a model every month, as we need time to digest each model's results and pinpoint inefficiencies in the market" – fund manager, tier one asset management firm.*

There are four main barriers to model go-live: recoding, fixing bugs, testing, and approvals. While the majority of sell-side institutions found the approvals process a particular challenge, they were of the belief that this human process would not easily be sped up, due to accepted bureaucracy and layers of approval. Both buy- and sell-sides value the rigorous nature of the approvals process itself, to ensure that models are fit for purpose.

The buy-side's priority is to speed up the recoding time, with 82% citing it as the part of the process they would most like to accelerate. This may be due to the fact that the buy-side's developer teams will likely be smaller than the sell-side's, due to the size of the scale and resources available at the respective institutions.

> *"We have very rigorous risk checks in place, so we're focusing on speeding up the due diligence process" – tier one investment bank.*

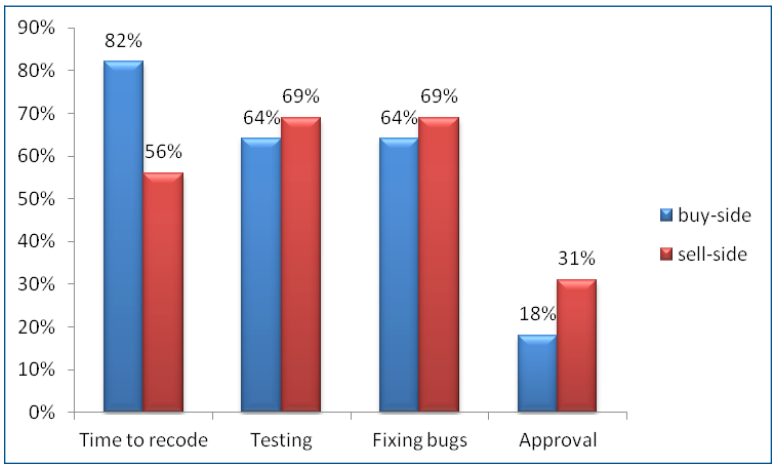

Fig. 7, What part of the model integration process would you most like to accelerate?

When asked what the ideal integration time would be, respondents sometimes appeared despondent. Many were resigned to the fact that models simply cannot be integrated without iterations of edits and approvals. Interestingly, academics were looking for quite short turnarounds, with 40% looking to reduce the integration time to mere hours. This potentially signifies a lack of appreciation of the bureaucracy and testing experienced within the large institutions.

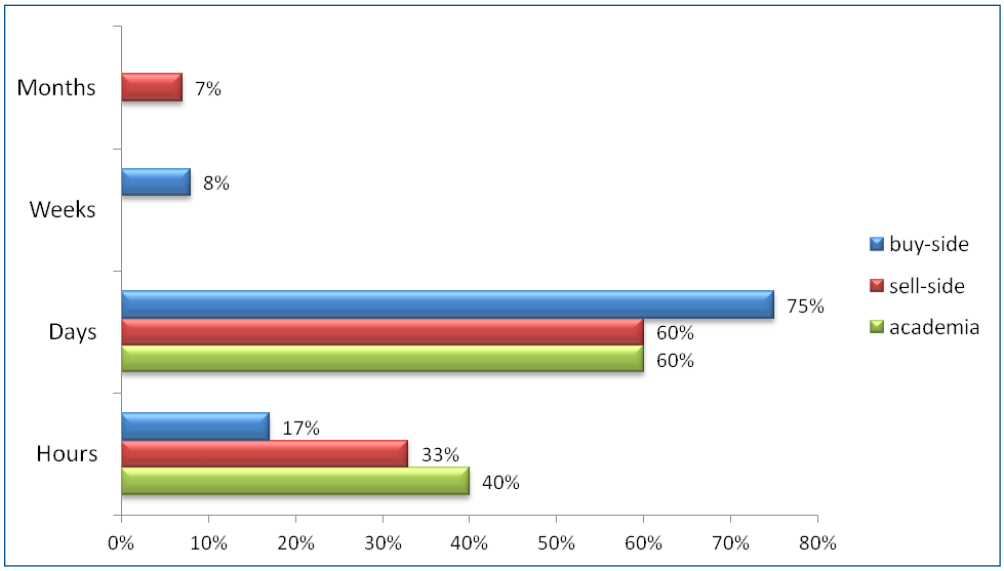

Fig. 8, How long would you ideally like the model integration process to take?

There are various ways financial institutions can speed up the model integration process and cut down on the time spent recoding, testing and fixing bugs. Technical programming environments facilitate rapid application development and direct implementation into production – reducing time, cost and operational risk compared to recoding.

Taking models directly into production, rather than manually

Incorporating technical computing applications directly into business-critical production systems can offer accelerated time-to-market and cost advantages. The alternative is to develop a model in an isolated environment, which is then redeveloped and translated into C++ (most commonly used language) which presents recoding risk. The recoded models are usually manually tested within a test environment and validated. This process is usually manually-driven, requires human intervention and is subsequently quite time intensive.

By taking models directly into production, no time is taken to recode into another language, C++ or otherwise. This potentially eliminates the recoding risk. Testing of these production processes can also be automated. This speeds up the model implementation and integration processes and frees up valuable IT resource, which could be redeployed to, for example, work on data frameworks and communication engines.

The sell-side, with its decades' old internal libraries of code, usually in C++, is traditionally against adopting production-ready models preferring to re-code, though there are some signs that attitudes are changing. The buy-side on the other hand is more agile and willing to integrate code into production more quickly.

Cost and risk are biggest concerns with model integration

> *"The most principled approach may take too long to optimise, however the incremental level of improvement may not justify the cost" – tier one investment bank.*

Cost (65%) and risk (62%) are the biggest concerns when integrating models into business processes. It was evident from feedback of all participants that the cost constraints relate to human resources, rather than technology investment. There are not enough quantitative analysts and developers within the organisations to carry out the model development, testing and implementation, with many firms resorting to prioritising development projects. However, by rationalising the development and implementation processes, it may be possible to achieve more.

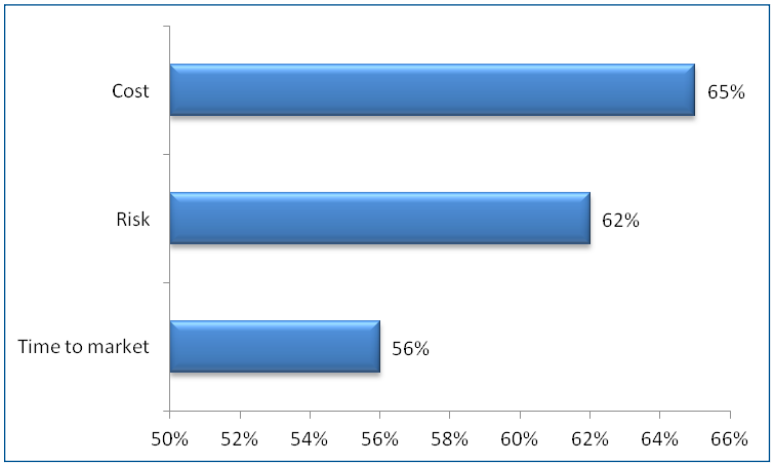

Fig. 9, The biggest concerns when integrating models into business processes?

5.0 Trading Strategy

Critical elements of a successful trading strategy

"Models are only as good as the data that goes into them" was the remark of one asset manager, and this is reinforced with the consensus that quality of data is the most critical element of a successful trading strategy. Financial institutions build their analytics around the data, so it is essential that data quality is high. A smart model is the second most critical element of a successful trading strategy, as cited by 54% of the respondents.

The sell-side puts most onus on data quality, with 69% citing it as the most critical element in a successful trading strategy; compared to only 43% of the buy-side, who prioritise smart models (71%), ability to respond quickly to market changes (57%), and good back-testing of data (57%).

> *"We built a mechanism to check for data quality issues. We're just starting to look at Twitter – this unstructured data will need more rigorous data cleansing" – fund manager.*

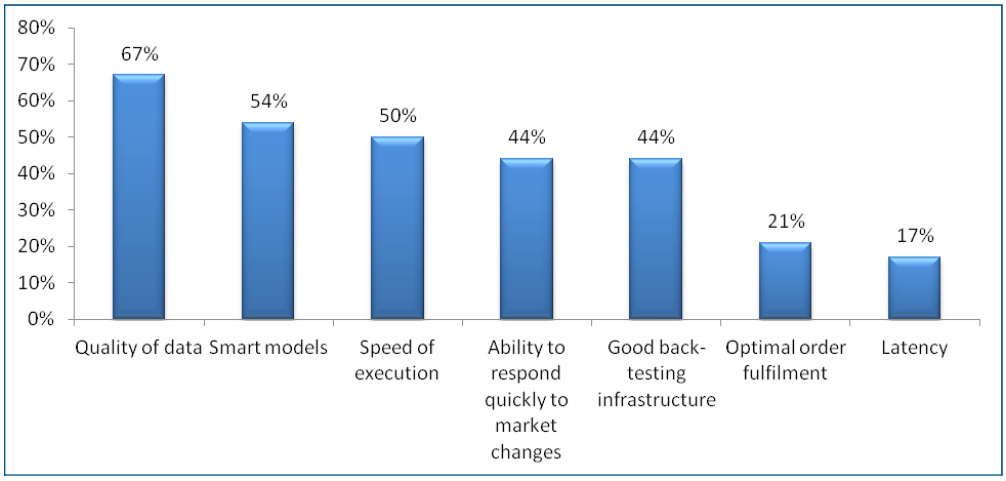

Fig. 10, Which are the most critical elements for a successful trading strategy?

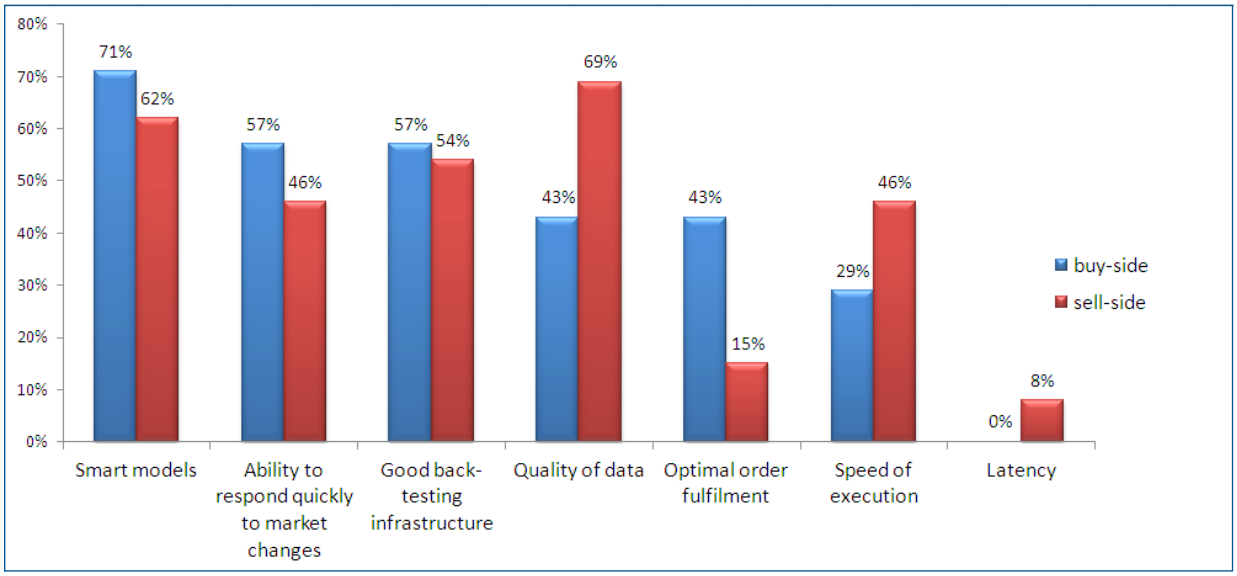

Fig. 11, The buy-side / sell-side split: Which are the most critical elements for a successful trading strategy?

Automated trading

> *"How can you execute a large order with little or no market impact? HFT. We're looking to increase automated trading" – tier one investment bank.*

Since the 2010 flash crash, and potential repeat occurrence, financial institutions have decided to increase the levels of automated trading (59%), rather than maintain the same level of automated trading over the next 12 months (36%), or move towards alternative trading models (5%).

Automated trading is a technique most widely used among the buy-side and hedge funds in particular. However, it is the sell-side which is leading the charge to increase levels of automated trading as they try to capture revenue from placing trades more quickly and at lower cost within the increasingly fragmented trading infrastructure.

67% of the sell-side is looking to increase levels of automated trading, compared to 46% of the buy-side. In fact, 31% of buy-side firms believe that automated trading has had its day and they will be moving towards alternative trading models – for example, bespoke, human-driven trading models.

Due to the nature of automated trading, if a model is flawed, there will immediately be obvious losses incurred. As such, it is critical that automated trading models are fully tested and fit for purpose.

High frequency trades now account for more than 50 percent of trading volume in some global markets, whereas seven years ago it was virtually absent – according to recent research from Capital Markets Cooperative Research Centre[2].

[2] *Securities Technology Monitor, Researcher: Dark Trading Bad, HFT Good (June 5, 2012)*

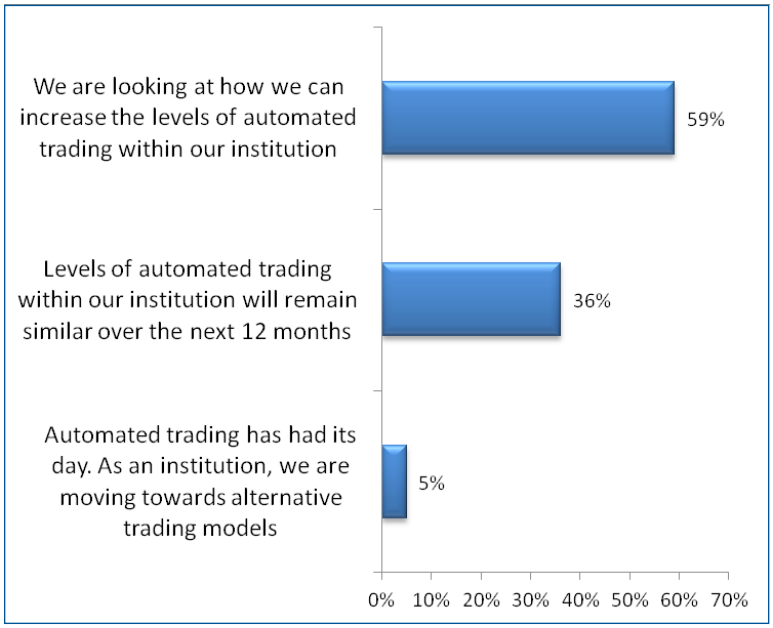

Fig. 12, Levels of automated trading in use at financial institution

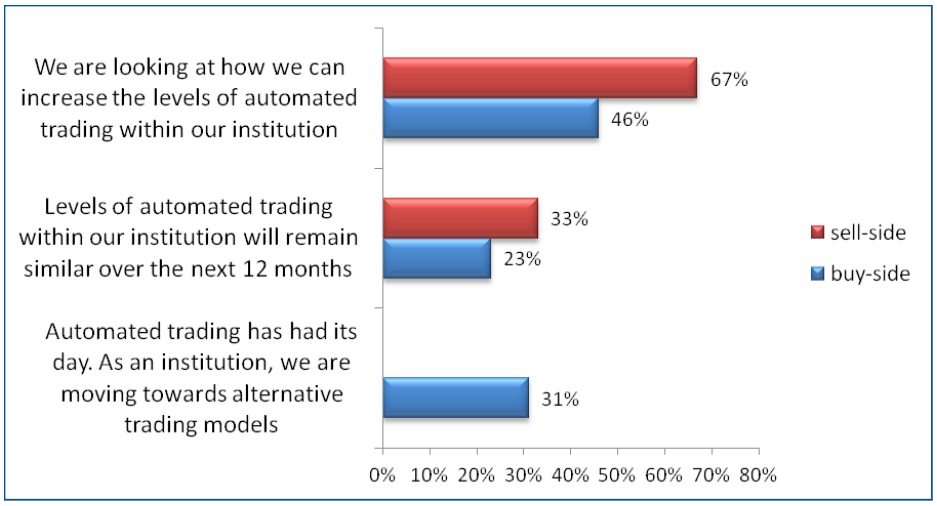

Fig. 13, The buy-side / sell-side split: Levels of automated trading in use at financial institution

6.0 The data deluge

Challenges associated with the data deluge

"Garbage in, garbage out – data quality is key" – tier one investment bank

The biggest challenge associated with the data deluge is data quality, as cited by 68% of respondents. Creating effective models (57%) and data variety (38%) were also among the main three challenges. Data volume came in fourth, with only 32% citing it a challenge.

"We encounter more challenges with simulated data, than with real data." – wealth manager.

The sell-side finds data quality the most significant challenge of the data deluge, as cited by 82%, compared to only 60% of the buy-side. One buy-side respondent stated that the biggest challenge his firm faced as a result of the data deluge was 'noisy models' – i.e. models producing incorrect or incoherent outputs.

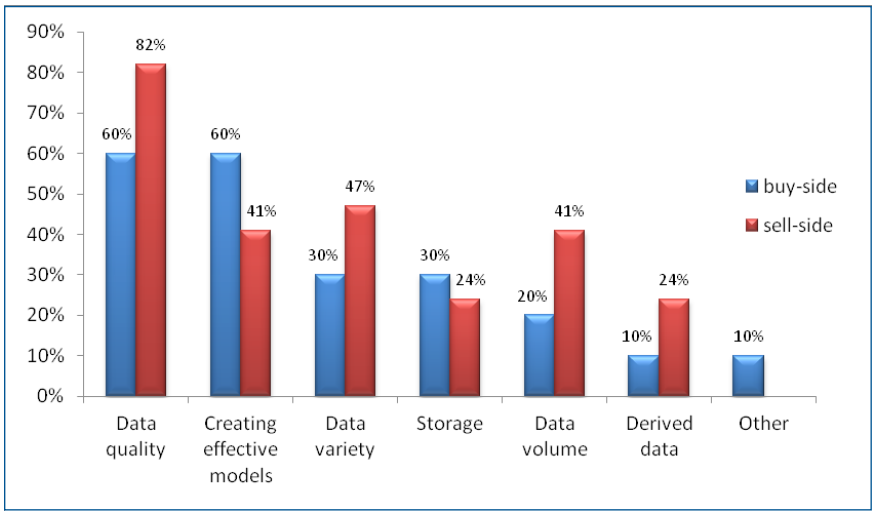

Fig. 14, What is the biggest challenge associated with the data deluge?

What size datasets are financial institutions dealing with?

The datasets being dealt with are in general not as large as externally perceived: 49% of financial institutions are dealing with datasets in gigabytes; 28% with megabytes. The sell-side is grappling with larger datasets than the buy-side, with 19% of sell-side respondents handling datasets of terabytes.

However, what this audience called out was that it's not how much data you have, but how you use it that counts. Good analytics and models, and efficient use of computing methodologies – e.g. incorporating models and analytics within a data warehouse or good application of parallel computing techniques – can alleviate pains of the data deluge.

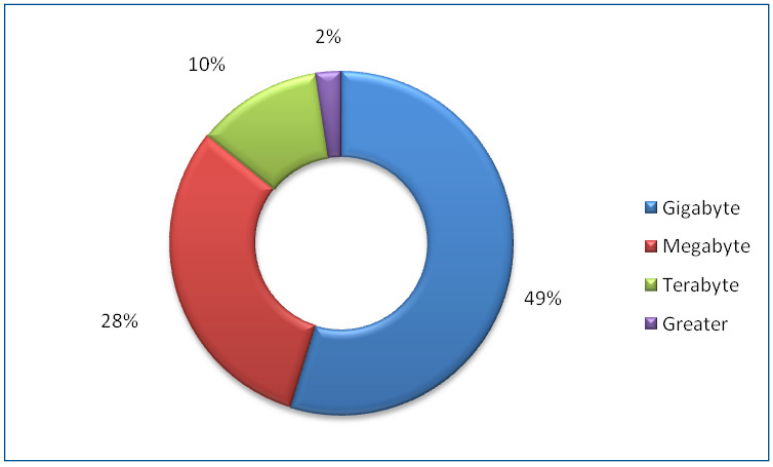

Fig. 15, On average, how large are the datasets you deal with?

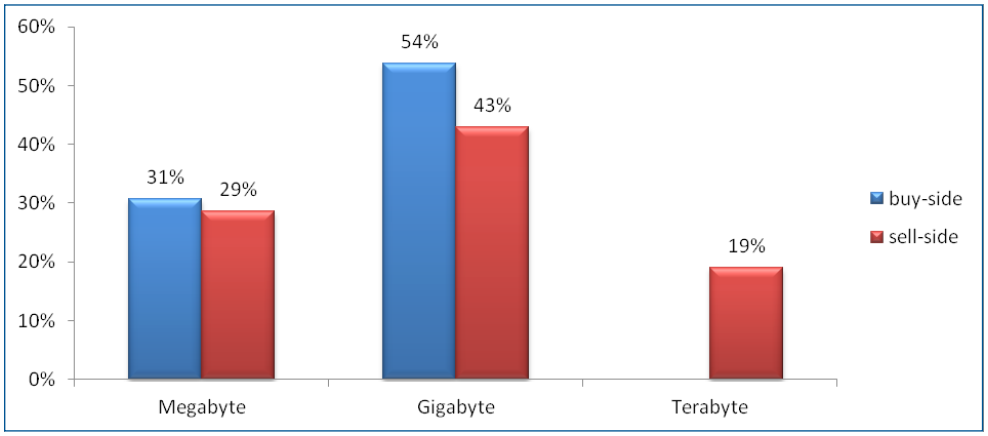

Fig. 16,The buy-side / sell-side split: On average, how large are the datasets you deal with?

7.0 Conclusion and recommendations

Models are vital to the success of financial services, but senior sponsorship is lacking

Models are integral to the success of financial services – 88% of financial institutions believe they would lose their competitive edge if they were operating 'poor' models. Yet models and the processes that surround them are rarely a Board-level priority, more commonly, they are deferred to quant and IT teams.

There is a need for Board-level sponsorship and appreciation of product lifecycle, effectively process audits. A board priority should involve evaluating the complete lifecycle of a model, from conception, through coding, development and testing, to performance analysis over time. This is particularly necessary on the sell-side, where competitive pressures are greatest, including from new buy-side challengers, and regulators at their most demanding. Yes, this requires engineers to engage with non-engineers within financial firms, and to accept each others' fallibility to determine together more holistic, technically effective and culturally-acceptable systems.

Model risk must be reduced in the production process

Recoding is a hangover from the 1990s. Today, model implementation directly in production is very achievable. Not only does this eliminate the need to recode – which itself can add risk – it also dramatically speeds up the model integration process. Sell-side institutions in particular need to shake up their legacy infrastructures from the spendthrift days of the 1990s and early 2000s.

Buy-side's lack of model governance could lead to inconsistencies

The buy-side has always had the freedom and a flat structure to support innovation, allowing these firms more autonomy with process and the flexibility to take models into production more quickly. However, whereas the sell-side suffers bureaucracy which can hinder innovation, the buy-side would do well to apply more governance around their free-form processes. It does not have to constrain agility, far from it. Technologies are available off-the-shelf to enable robustness around development, testing and implementation processes.

Levels of automated trading will increase

Automated trading is a topic of ongoing debate, with nervousness around potential repeats of the 2010 flash crash and recent market-impacting bad trades. However, the industry, regulators and politicians can benefit from looking under the hood at applications of automated trading, particularly to understand how need differs from sell-side to buy-side, and particularly how it can benefit market liquidity provision. In general, financial institutions are looking to increase levels of automated trading, with the sell-side leading the charge as better automated trading not only enhances their competitive edge, but also creates market liquidity and reduces volatility which is actually what governments and regulators are demanding.

The buy-side is leaning towards bespoke, human-driven alternative trading models. A significant conclusion of this research is that the buy- and sell-side agree that more robust and faster implementation of trading – and risk – models are key to better market performance. This can reduce the likelihood of bad trades and provide more effective risk monitoring.

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