Change in Investment Landscape Due to Technological Developments

Mike Chen

INTRODUCTION

> *"This article is not written by a large language model (LLM) but by a real human."*

That one has to put that statement above is an astonishing fact that, even five short years ago, most people would have thought laughable. Of course, technology and its rapid advances and pervasiveness have dramatically impacted every facet of our lives and society. In one way or another, almost all industries and economic activities have been impacted by technology. Finance is no exception. In recent years, a particularly powerful form of technology, namely AI (of which LLM is the latest example), is poised to cause disruptive change on par with, if not more than, the steam engines during the industrial revolution, the computers in the information revolution, and the internet during the communication revolution.

In this article, we look at how technology has changed the institutional asset management industry in recent years. We look at this from the perspective of both fundamental and quantitative investors, in addition to non-investment functions such as marketing, operations, etc. We also offer a few hypotheses on how technology may further impact institutional investment practices in the near future. First, we briefly discuss three major technological trends driving such secular change.

THREE SECULAR TECHNOLOGICAL TRENDS DRIVING THE WORLD (INCLUDING INVESTING)

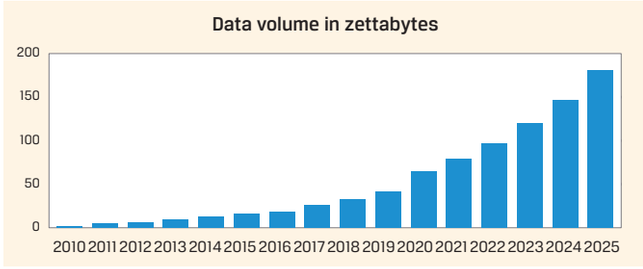
The broad trend of secular technological change can be decomposed into three major themes:

- Explosion of available data
- Exponential growth of computing power, and
- Availability and breakthrough of sophisticated algorithms (ML, NLP, Transformers/GenAI)

Data is the first theme. Since the internet came on the scene in the mid-1990s, later followed by the widespread availability of smart devices in the 2000s, the volume of captured data has grown dramatically. It has been estimated that the quantity of data created and captured by humans since the inception of time roughly doubles every two years [WEF, 2022]. This vast amount

Mike Chen
Head of Next-Gen Quant, Robeco

Figure 1
Global data growth



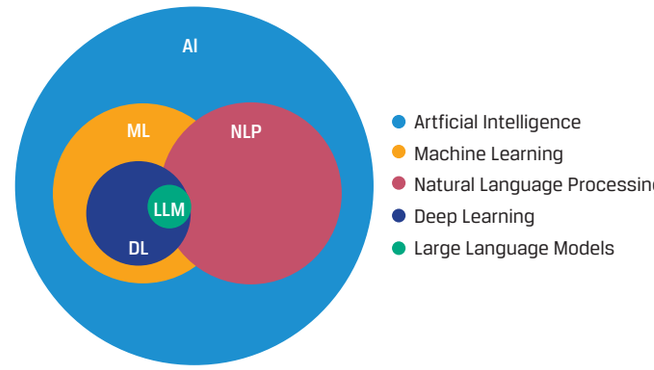
Source: [Pangarkar, 2025]

of data gives those with the ability to store, process, and analyze them an advantage on information and intelligence, leading to possibly better decisions. Figure 1 above illustrates the growth of data.

The second theme is the exponential growth of computing power. Everyone has heard of the Moore Law [Moore, 1965], which states that computing power doubles approximately every year.[1] This exponential growth in computing power, compounded over decades, resulted in everyday people owning portable devices with computing capability on par with those of supercomputers from just 15 to 20 years ago. Figure 2 illustrates this tremendous growth. The availability of computing is further supercharged by the emergence of cloud computing services, which further lowers the access barrier to essentially unlimited computation power.

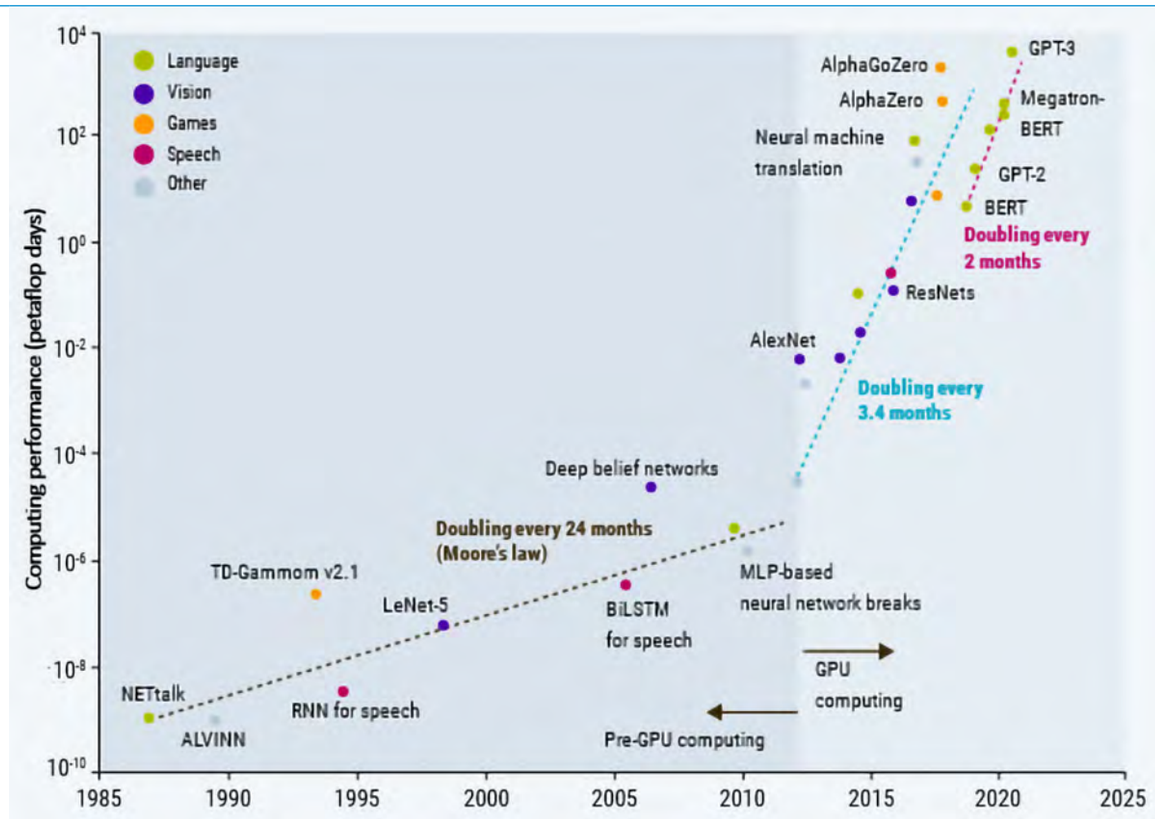
The final theme of secular technological improvement is the widespread availability and continued evolution of sophisticated algorithms, specifically AI. The simpler AI algorithms have been available for decades, but until recent growth in data and computing, they were not practically feasible. With the first two themes mentioned above, this is no longer true. Furthermore, in the past decade, we've seen tremendous innovation in these algorithms as well, such as the breakthrough invention of transformers [Vaswani et al, 2017], leading to the emergence of large language models (LLM) and the tantalizing possibility of artificial general intelligence (AGI). Figure 3 below gives the current AI algorithm's landscape, with the latest advancement, LLM, emerging in the last decade.

Figure 3
Sophisticated algorithms are now practical, and new advances are emerging rapidly



Source: Robeco

Figure 2
The exponential growth of computing power, driven in recent years by GPUs



Source [Zhu et al., 2023]

TECHNOLOGY'S IMPACT ON INVESTING: BETTER INSIGHTS AND EXECUTION

If applied correctly and artfully, the advancements described above can lead to an advantage in extracting alpha from the financial market. This advantage comes from three particular aspects: faster speed, more sources of information, and better information processing.

TECHNOLOGY'S IMPACT ON QUANT INVESTING

For quantitative investors, it is easy to see how technological advancements can improve their investment process. Certainly, quant investors have always relied on data, computing, and algorithms in their investment processes. For example, classical quant investment techniques such as factor investing applied linear or logistic regression algorithms on data from financial statements in desktop computers to derive "alpha ranks" on securities in their investment universes, and buy the best ranked securities and sell the worst ranked ones. Since Quant investors have always used computers in their investment process, the speed aspect of alpha extraction has always been there. However, recent technological improvements have broadened quants' information sources and enabled better processing of that information, thereby deriving better investment insights.

With big data, massive computing, and advanced algorithms, the realm of possibility has dramatically expanded for the savviest quant investors. Rather than being limited to financial statement data, which tends to be backward-looking and usually comes with a time lag, quant investors can now use alternative data processed by sophisticated algorithms running on large computing clusters to derive pertinent investment insights that they've always had an interest in answering, but previously didn't have means to do so. Below, we list the enabling technologies and some examples of the new investment insights they enable for quant investors:

- Alternative/big data:
  - Credit card spending: real-time B2C revenues
  - Shipping manifest: goods imported and exported, and their values
- Machine learning (ML):
  - Security return prediction: estimate of security returns based on linear, *non-linear*, and *interaction* combinations of input features. Traditionally, quant investing has been limited to linear input combinations. An example of this approach can be seen in [Gu, Kelly, and Xiu, 2020], where the authors used machine learning algorithms such as boosted trees and neural networks to combine input features to estimate securities returns. The authors noted that in addition to linear combinations, these ML algorithms were also able to deduce security return's relationship with non-linear and interactive combinations of input features.
  - Security categorization: Use unsupervised clustering algorithms to group similar securities based on various characteristics such as return, supply chain, technologies used in the production process, etc., to enhance risk management capabilities. For example, see [Dolphin, Smyth, and Dong, 2023].
- Natural Language Processing (NLP):
  - Sentiment analysis: NLP applied to appropriate textual data can reveal customer, management, or employee sentiments towards various topics. As NLP techniques have advanced from bag-of-words in the early 2000's to the latest large language models, the capability to extract textual sentiments salient and subtle has increase by leaps and bounds. For the paper that kicked off NLP in finance, see [Loughran and McDonald, 2011].
  - Entity identification: NLP can extract entities from textual information, such as suppliers, customers, or competitors, thereby enriching Quant's understanding of a company's competitive landscape.

From above, we see that technology has increased quants' capability to drive better investment decisions. However, careless application of these advanced techniques will likely not result in better *out-of-sample* performance, but rather in disappointment. One of the major concerns of quantitative investing is the problem of overfitting. Given the very high degrees of freedom inherent in these new techniques, this problem (and other such as look ahead bias, etc.) are even more exacerbated. Furthermore, finance is inherently different from other disciplines for which ML and NLP have excelled as the financial market is adaptive, non-stationary, and not always rational. All this is to say caution, common sense, domain knowledge must be exercised when applying these novel approaches to finance. For common pitfalls associated with financial ML and NLP, and practices to mitigate some of these issues, see [Chen and Zhou, 2023].

Next, we switch to see how technology changes and potentially benefits fundamental investing.

TECHNOLOGY'S IMPACT ON FUNDAMENTAL INVESTING

Although historically, fundamental investors have been less reliant on technology than their quantitative counterparts, technology's advances have been too dramatic to ignore. Fundamental investors have increasingly integrated technology into their investment process in recent years. This trend becomes increasingly prevalent with the advent and popularization of advanced AI technology, particularly NLP.

Fundamental investors can derive all three advantages from incorporating advanced technology into their investment process[2]: faster speed, broader sources of information, and better information processing. The main limitation of the fundamental investment process is that it is mainly dependent upon human investors, who get tired, have limited attention spans, have their own biases and idiosyncrasies, and cannot easily scale. Some of these limitations can be overcome by coupling human investors with technology. For example, by using LLMs, summaries of large amounts of news articles and analyst reports are now possible, allowing human investors a quick overall grasp of an investment topic, current market conversations and trends, or nuanced political developments. If the human investor finds

a particular point in the summary interesting or critical, he or she can then spend more time drilling down into the details, but now with much better direction of what to look for.

In addition to broader information sources and better information processing to help alpha idea generation, technology can also help fundamental investors scale in building various customized portfolios demanded by large institutional asset owners by leveraging optimization techniques, measuring risks associated with the various portfolios under management, or executing trades better with lower costs and market impacts. Figure 4 below gives more examples of where technology can enrich the fundamental investment process.

Similar to the quantitative investment section above, a few words of caution for technology's application to fundamental investment is warranted as well. Specifically, superficial application of advanced techniques mentioned here likely will not result in superior performance. One reason for this is that financial markets are adaptive. Much like the algorithms discussed here, markets also learn. If most fundamental investors apply these algorithms in a similar manner on the same set of securities, it is unlikely that there will be much alpha to be extracted. Even worse than not extracting alpha, superficial application of these advanced techniques could potentially get investors in trouble. Since these algorithms are trained on their input data, they also exhibit the same bias, prejudice, and blind spots their training data exhibits. To avoid potential troubles, it is essential for the fundamental investor to have a good grasp of the technology they deploy, the data based on which it is trained, its strength and weaknesses and the suitability for task upon which it is deployed.

TECHNOLOGY'S IMPACT ON NON-INVESTMENT PROCESSES: EFFICIENCY AND SCALE

Asset management is not solely comprised of investing; other functions such as sales and marketing, client servicing and reporting, risk management, operations, legal and compliance, sustainability and stewardship, etc., are all essential functions within an asset manager. When integrated thoughtfully, technology holds the promise to improve efficiency and increase scalability for all of these functions. Given the relentless margin pressure under which asset managers operate and the asset management industry is characterized by high operational leverage and economy of scale, there is a great incentive to incorporate technology to both reduce cost and increase scale. We now look at a few examples where technology can be thoughtfully incorporated to improve non-investment-related operations.

Sales and account management is the ultimate job where human-to-human relationships and connections are critical. Even in this function, technology can be incorporated to make the process better. For example, a salesperson needs to prepare insights into the client and associated talking points before each meeting. Perhaps he or she needs to anticipate where the conversation could go and prepare for potential solutions to the client's problems. Training LLMs on meeting notes from previous client interactions can surface insights into a client's needs and challenges and highlight them to the salesperson as they prepare for the meeting. AI techniques can elevate digital sales, e.g., lead generation and lead qualification, allowing more focused sales efforts towards prospects with a higher probability of converting. This is pertinent for small and mid-sized asset

Figure 4
Steps in the fundamental investment process and how technology can augment them

Security Screening (Idea generation)	Company Research	Portfolio and Risk Management	Trading and Execution
• Algorithms used to systematically screen opportunities particularly on the stort side (e.g., scanning for the use of certain words in sell-side analyst reports which data scientists have found to be correlated with good shorts) • More companies screened with more sophisticated algorithms • More data inputs including traditional (e.g., cash flows, profitabilty and alternative (e.g., satelite data, credit card data) • More internal systems to share ideas across teams	• Integrated approach across fundamental research and data science teams • Dedicated data sourcing activity covering new sources • More new data inputs to fundamental analysis • Platform and tools to run custom data analysis to support or challenge investment case • Unique information collected over many ears turned into quant data inputs (e.g., management quality) • Pure data model based valuation as a cross-check on fundamental valuation	• Complex portfolio risk attribution and scenario modelling • Fully automated position sizing and portfolio optimisation based on upside/downside, stock correlations and exposures (beta, sector, style, geography and liquidity) • More accurare measures of true idiosyncratic alpha (i.e., stripping out factor effects) • PM/Trader capital allocation models yied tot alpha size and volatility • PM performance analysis (vs. performence of all analyst recs), with compensation based on alpha (rather than pure P&L) relative systematic quantification of opportunity set and exposures	• Automated trading based on results of optimisation process • Connection to multipe platforms to ensure best execution • Short term event driven trading models to size positions (e.g., trading around corporate earnings events)

Source [Miranda, 2018]

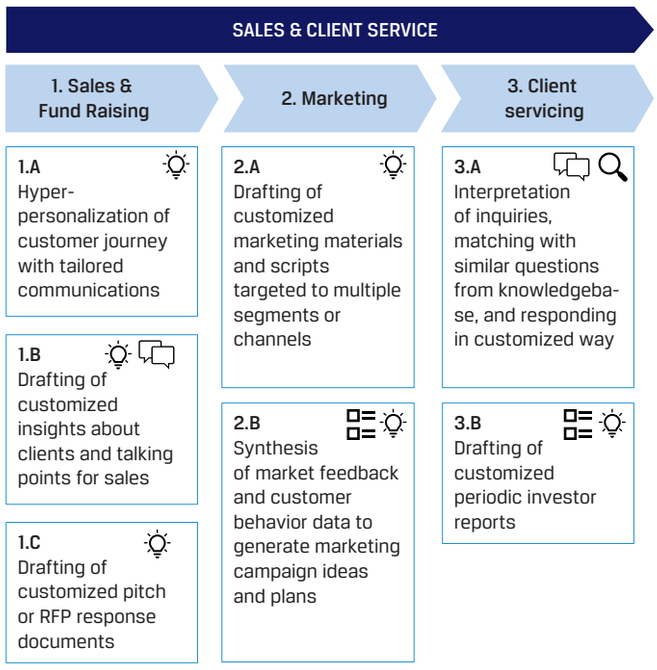
managers that do not have the salesforce of larger peers, as it allows them to punch above their weight class.

After clients are acquired, they must be serviced. For an account manager with a large and diverse client base, some accounts may need relatively routine services, while others may have more unique needs and require individualized attention. Clustering techniques from machine learning can be used to group clients by various attributes. These client groups can then be further analyzed for common investment solutions each group typically utilizes, how each group can be serviced to maximize effectiveness, etc. For clients with mostly routine requirements, technologies such as GenAI can be used to service many of their needs, freeing up account managers to focus on clients with bespoke needs.

Below, we list a few more examples of how technology can improve non-investment-related asset management operations. Additional use of technology to enhance existing sales and marketing processes can also be found in Figure 5:

- Client Q&A can be made quicker by training bots to answer commonly asked questions, taking clients' holdings and their related market developments and news into account. Reporting can also be generated similarly.
- Requests for proposals (RFPs): LLMs can be trained on previous RFPs to answer questions in the firm's unique style, discussing the firm's strengths and differentiating points, etc.
- For compliance, various detection algorithms can be run for trade surveillance (e.g., to detect suspicious trading behavior), communication monitoring (e.g., to detect policy violations or potential misconduct), etc.

Figure 5
Additional use of tech to improve sales and marketing processes within investment management



Source: Oliver Wyman
Note that no technology is 100% accurate and foolproof, and errors, omissions, or incompleteness are likely regardless of how advanced the deployed technology is. Thus, it is important to still have "human-in-the-loop" in these processes. However, when deployed correctly, technology can dramatically cut down on human time and labor, thus increasing efficiency, lowering cost, and increasing scale.

HOW TO ENSURE SUCCESSFUL TECHNOLOGY ADOPTION AND UPSKILLING?

The deployment of technology into the various asset management processes is all good and well, and most people can see the logic behind how this can benefit the clients and the business itself. The more critical and challenging question is how? Given that asset managers already have established processes in place and people in the asset management industry are already busy during the day with their assigned responsibilities, how can employees have the time and motivation[3] to learn new skills, figure out where efficiency can be gained, and re-engineer their day-to-day processes? These questions are difficult and necessary to get right if technology is to be successfully deployed and benefits from it reaped. Change management is a field in itself, and we refer the interested readers to read, for example, [Westerman and Bonnet, 2015]. Needless to say, senior management must take the lead here to drive this change. Below are some high-level suggestions on how to drive this transformation:

- Motivate why incorporating technology is necessary. Demonstrate the upside of more technological inclusion: employees can offload more repetitive work and focus more on high-value tasks.
- For each functional group, assign technology champions and create free time for people to experiment with new technology.
- Celebrate wins, disseminate lessons learned, and normalize failure as part of the process.

POTENTIAL FUTURE EVOLUTIONS: FROM EFFICIENCY TO INTELLIGENCE

In this article so far, the astute reader will have noticed that technology is used for relatively mechanical tasks to increase efficiency. Could it be possible that in the (near) future, technology evolves to a stage where it can be used for its intelligence? The concept of Artificial General Intelligence (AGI) has been a dream of technologists since the mid-20th century, and it is outside the scope of this article to discuss whether it'll happen or not, and if so, how soon. However, we postulate some investment functions that humans currently carry out, but we believe they could be possible, either augmented or replaced by technology, in the (near) future.

First, looking at quant investing. Researchers and PMs are the primary drivers of investment ideas and portfolio position adjustments. In the (near) future, it may be possible for technology, in this case LLMs or other forms of AI, to generate research ideas or recommend adjustments in portfolio positions. An AI may generate research ideas by getting an understanding of a quant strategy's alpha model, understanding where improvements in the model can be made by scanning known finance literature and market materials[4] and compare its knowledge with the current quant model to suggest new research directions based on its identified model deficiencies. Similarly, it may analyze a portfolio's holdings. Based on its understanding of

the holdings and how each has typically reacted historically under different market regimes and types of market news, combined with the latest market development, to suggest changes in the securities held. In both scenarios, human quant investors go from being direct drivers of research and portfolio positioning to becoming more akin to supervisors of AI algorithms.

Perhaps fundamental investment managers would not like to give technology such prominent and direct driving roles as in quant investing. However, for this investment style, technology could still replace or at least augment some functions currently conducted by humans. For example, fundamental investment teams typically comprise portfolio managers and analysts. Analysts would propose the bull and bear cases for each security they cover, and portfolio managers would decide to go overweight or underweight based on these analyst cases. One challenge for analysts is the number of securities they can cover. By leveraging AI, one may train it to behave like analysts and generate bullish and bearish cases for securities in an extended investment universe, thereby expanding a strategy's investment opportunity set.

CONCLUSION

This article discussed how advanced technology, driven by data, computing, and algorithms, has impacted the investment industry. Truth be told, this isn't a recent phenomenon, and the investment industry, along with all other human economic activities, has evolved and changed along with technological advancements. At the dawn of the "age of AI", technology's capability seems to become ever more powerful and its promise ever more tantalizing. For investment managers, it has the promise to expand its alpha extraction capability, increase its scale, and/or lower its cost. The use cases described here are rather general and high-level, as each investment manager's specific case for technology incorporation differs. Hopefully, this article clarifies that for those managers wanting to stay at the forefront of the investment industry, leveraging technology is not a luxury but a necessity.

References

- [WEF, 2022] The World Economic Forum. "How industrial data can help unleash productivity, innovation, and sustainability", https://www.weforum.org/stories/2022/05/industrial-data-can-unlock-our-sustainable-future-heres-how/, May 13, 2022.
- [Pangarkar, 2025] Pangarkar, T., "Data science statistics 2025 by best solution, easy insights", https://scoop.market.us/data-science-statistics/, Jan 13, 2025.
- [Moore, 1965] Moore, G. "Cramming more components onto integrated circuits", *Electronics*, Apr. 1965.
- [Zhu et al., 2023] Zhu, S., Yu, T., Xu, T., Chen, H., Dustdar, S., Gigan, S., Gunduz, D., Hossain, E., Jin, Y., Lin, F., Liu, B., Wan, Z., Zhang, J., Zhao, Z., Zhu, W., Chen, Z., Durrani, T., Wang, H., Wu, J., and Pan, Y. "Intelligent Computing: The Latest Advances, Challenges, and Future", *Intelligent Computing*, vol. 2, 2023.
- [Vaswani et al, 2017] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A., Kaiser, L., and Polosukhin, I. "Attention is all you need", *Advances in Neural Information Processing Systems*, vol 30, 2017.
- [Gu, Kelly, and Xiu, 2020] Gu, S., Kelly, B., and Xiu, D., "Empirical Asset Pricing via Machine Learning", *The Review of Financial Studies*, vol. 33, May 2020.
- [Dolphin, Smyth, and Dong, 2023] Dolphin, R., Smyth, B., and Dong, R. "A Machine Learning Approach to Industry Classification in Financial Markets", *Communications in Computer and Information Science*, vol 1662, 2023. https://doi.org/10.1007/978-3-031-26438-2_7
- [Loughran and McDonald, 2011] Loughran, T., and Macdonald, B. "When is a liability not a liability? textual analysis, dictionaries, and 10-Ks", *The Journal of Finance*, vol 66, 2011
- [Chen and Zhou, 2023]. Chen, M., and Zhou, W. "On Machine Learning Applications in Investments", *The Handbook of AI and Big Data Applications in Investments*, The CFA Institute, 2023.
- [Miranda, 2018] Miranda, Stan. "Technology's impact on active investing", Partners Capital White Paper, https://partners-cap.com/insights/technologys-impact-on-active-investing/, January 2018.
- [Westerman and Bonnet, 2015] Westerman, G., and D. Bonnet. "Revamping your business through digital transformation", MIT Sloan Management Review, https://sloanreview.mit.edu/article/revamping-your-business-through-digital-transformation/, February 2015.

Notes

1 Specifically, the original Moore's Law, stated in 1965, states the number of transistor on a chip doubles approximately every year for the next 10 years. In recent decades the number of transistors on a chip doubles roughly every 2 years.
2 Versus the two advantages quantitative investors derived: broader information sources and better information processing.
3 The motivation piece here is critical. Most people's first reaction, upon hearing more technology is to be deployed into their daily work processes, is to fear for their job security.
4 Such as analyst reports, financial news, etc.