A First Perspective: The Transformational Influence of “Big Data” on the 21st Century Global Financial System

EXECUTIVE SUMMARY

Big data has arrived. The cheering din grows louder. Supporting the idea of a monumental data-stimulated change ahead in many disciplines, especially finance, information flows are rising at an exponential pace. A Google search on April 15, 2013, for big data revealed a gargantuan 2.2 billion entries, shrunk by using an advanced filter to a “paltry” 30.2 million items. Big data conferences, books, and articles proliferate. This essay defines big data, highlights its vast potential, acknowledges its limitations, sketches its transformational influence on the 21st century global financial system, mainly from an asset management perspective, and lists key capital market inquiries that might be well addressed by big data methods.¹

INTRODUCTION: “THE ACCELERATING EVOLUTION OF THE GLOBAL FINANCIAL SYSTEM”

Green eyeshade finance perished little more than a generation ago. A small group of grizzled veterans from the Great Depression still inhabited financial institutions as recently as the late 1970s. Performing more forensic archaeology on historical measures of economic and corporate vitality, these “statistical clerks” (as security analysts used to be known) were outfitted with pencils, spreadsheets, and adding machines the size of giant dictionaries in lieu of computers. These prototype modern capital-market soldiers engaged mainly in retrospective comparative analyses rather than forecasting. To satisfy the demand for prognostications, the illusion of forecasting was created by the manufacture of modified extrapolations of the past into the future. Like the medical and pharmaceutical fields, competition atomized research to cater to sponsoring institutions to the disadvantage of perhaps more rapid coordinated progress.

¹ The authors would like to thank the following for their contributions and comments to this article: Charlie Dolan, Bryan Besecker, Perry Beaumont, Chip Dickson, Aram Flores, Tom Higgins, Pete Johnson, Gary Maier, Steve Nagourney, Fati Naraghi, Kishlaya Pathak, and Dexter Senft.
The past four decades wrought prodigious change to the practice, principles, and technology of finance. Monroe calculators replaced printed bond yield tables. In turn, computers quickly superseded Monroe calculators. Bloomberg terminals and broadcast financial media introduced near real-time simultaneous dissemination of important financial market information. High-frequency trading advanced into the machine realm via APIs (Application Program Interfaces), with client servers co-located next to exchange servers to expedite processing speed. Asset management and dealer scale ballooned. Quantitative methods blossomed beyond simple statistics to sophisticated models.

Graduate programs in financial engineering began to sprout up in the in the early 1990s. Empirical analyses surpassed qualitative, subjective techniques. Investment and planning horizons both shortened (along with the burgeoning hedge fund industry) and extended for plan sponsors, endowments, and sovereign wealth funds. Globalization, disintermediation, and derivatization recast the financial system. Regulatory oversight converged more regionally than globally and could not fully keep pace with all the new products, new markets, and new techniques of the rapidly evolving global financial system. Many of the best and brightest students elected to pursue lucrative careers in finance over manufacturing, management consulting, science, medicine, law, and other professional fields.

Despite numerous welcome advances in economics and finance in the late 20th and early 21st centuries, the forecasting prowess of these social science disciplines has not been distinguished, as evidenced by the general capital market shock that greeted the arrival of the partially predictable “Great Recession” and the extended policy uncertainties as to how to best cope with its long aftermath. Like seismologists who can calculate the probability but not the timing of earthquakes, financial market prognosticators can articulate possible stresses but usually not their timing, magnitude, or implications. These shortcomings may be addressed in the 21st century.

This early third millennium already has posted an impressive list of milestone scientific achievements. The human genome has been decoded (2001). Earth-like planets have been discovered in other solar systems (2007). The Higgs-Boson particle (2012) presumably has been confirmed.

And the best advances are yet to come, especially in better understanding and forecasting the path of the incredibly complex global financial system that serves the needs of more than 7 billion human beings currently populating approximately 200 nations. Under the auspices of big data, substantial aid is on the way to better decipher and navigate the intertwined financial system realms of economics, regulation, corporate finance, asset management, risk, product innovation, insurance, technology, and marketing.

As shown in Exhibit 1, world curiosity about big data has skyrocketed. Since mid-2012, big data has partially been credited with U.S. President Obama's re-election. And big data has been featured at the World Economic Forum in Davos in 2012 and the Council of Foreign Relations in 2013 as well as in such publications as The Wall Street Journal, the Financial Times, The New York Times, Harvard Business Review, CFA Institute Magazine, Fortune, Foreign Affairs, and spawned conferences around the world like “Big Data in Africa.”2 In addition to abetting actuarial methods, cosmological inquiries, meteorological predictions, unraveling quantum and criminology mysteries, aiding epidemiological studies, advancing life sciences, and expediting business logistics, these articles envision the construction of more accurate economic and business predictions as well as improved decision-making processes thanks to big data.

The swift amplification of the big data din may foster doubts by some seasoned capital market veterans. After all, evanescent market fads are common. And “catchy-phraseology hype” sells in futurology. False prophets of revolution litter the prediction landscapes of economics, capital markets, and technology. Recall the excessively enthusiastic expectations for fractal market analysis in the early 1990s as well as “B2B” and “e-commerce” in the late 1990s. For example, “horror of horrors,” shopping mall obsolescence was presumed by the inevitable surrender by consumers to the glories of online shopping. But in our view, the forthcoming successful application of big data methods will disappoint jaundiced cynics.

The concept of big data, including the search for regular signals to better predict the future, has been around since the dawn of humanity. Effectively, big data is simply a new name for an old and universal undertaking: the acquisition and application of new information confer competitive advantage throughout the economic system and speed progress in all fields.

Through history, these data surges are a series of stochastic jumps rather than continuous flows. And each can be characterized by a different source of information expansion. The seafaring “Age of Discovery” in the 15th and 16th centuries was predicated on new navigation information. The accumulation of data spurred the Scientific Revolution in the 15th-17th centuries, which in turn begot the Industrial Revolution of the 18th and 19th centuries. Under the tutelage of such business luminaries as Alfred Sloan, W. Edwards Deming, and Peter Drucker, modern corporate management came to rely upon the systematic acquisition and interpretation of new information. For decades, successful firms have set out to learn as much as possible about their political environment, customers, products, costs, and competitors. And all major sports now routinely prowl for fresh data-driven guidance on legitimate performance enhancement.

Despite exponential technological advance over the past century with attendant societal benefits, information harvests, information analyses, and information-based transformation of many institutional practices in financial services still remain in an adolescent phase in the early 21st century. Historical records have
Over the long run, big data may come to be viewed as the successor to the Internet in terms of revolutionary impact.

Technology frames big data by the 3 Vs: Volume, Velocity, and Variety. Simply, the quantity, speed, and diversity of information flows are expanding at a geometric rate and thereby producing data to be analyzed and possibly to be acted upon.

BIG DATA DEFINED

Introduced by NASA researchers Michael Cox and David Ellsworth in 1997 and popularized by various technology firms, especially IBM, big data can seem elusive. Poll five sources in search of a definition and expect five different replies.

Technology frames big data by the 3 Vs: Volume, Velocity, and Variety. Simply, the quantity, speed, and diversity of information flows are expanding at a geometric rate and thereby producing data to be analyzed and possibly to be acted upon. Analytically, big data can be further framed by drawing a distinction between “insight generation” and “methodology.”

As applied to financial markets and depicted in Exhibit 2, big data encompasses the following four main areas:

- **Insight Generation**
  - evaluating internal organizational data in search of “unrealized information” that enhances functional effectiveness (e.g., more precise calculation of internally generated cash flows by issuers to optimize timing of external financing)
  - sifting external data in pursuit of new perspectives and “competitive gold” (e.g., national and local housing demand and supply data)

- **Methodology**
  - constructing new analytics and statistics (especially correlations) to uncover and to test the meaningfulness of heretofore “unrealized internal and external information” (e.g., acquiring a better understanding of performance and return attribution in a multi-asset class portfolio through comparative portfolio/index analytics)
  - information can be made beautiful (e.g., see Edward Tufte’s work); developing new data visualization techniques that, in conjunction with novel analytics, reveal previously unknown insights about businesses and markets (e.g., fabrication of “efficient visualization ergonomics” to scan financial market data)

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Key Examples of Big Data Global Financial System Inquiries

From a near-inexhaustible set of possibilities, the following representative questions might best be investigated through big data methods:

1. Which geopolitical risks are most likely and what will be their impact on global financial markets? Can a reliable early-warning risk system be devised?

2. How will the global economic system and related global financial system evolve over the course of the early-to-middle 21st century? Can the speed of the “Grand Convergence” of emerging market (EM) to advanced economy (AE) status be calculated? Which continents, nations, industries, and issuers will fare best? How will currencies, commodities, equities, yield curves, public debt burdens, and exchanges be affected?

3. Do trends in social media amplify prediction prowess? Will big data enable a whole new generation of more precise real-time measures, models, and visualizations of macroeconomic (especially growth, inflation, trade), industry, corporate, and market performance, risk, and volatility? Can and will risk be decomposed into finer segments? Can technological progress and human capital development be better measured?

4. Will new information lead to timelier and more astute application of economic policies as well as to the invention of new policymaking tools? Can knotty political-economic problems like the appropriate role government in markets be better sorted out? What will the effects be on public and private sector operating and financial methods? What will be the effects on asset management?

5. Are directional changes in social media trends and country, asset class, sector, and issuer capital flows leading, lagging, or coincident performance indicators? What will be found in correlations of capital flow movements with volatility, total return, debt ratings? Will calculations and comparative analyses of security turnover ratios by country, asset class, sector, and issuer serve as a liquidity proxy and possible early warning indicator?

6. Would analyses of broader macro classifications (e.g., North vs. South, Latam vs. Africa, AE vs. EM, population growing vs. population shrinking, large vs. medium vs. small economies, positive trade balance vs. negative trade balance) generate new investment strategies?

7. Are there regular “timing effects” (elections, auctions, M&A, IPOs, credit supply, key data releases, time-of-day, day-of-the week, monthly, quarterly, year-end, seasonal) for global and local markets as well as by asset class?

8. Do markets behave differently during global triple-witching hours versus a triple-witching hour in just one local market? Are prepayments of amortizing assets globally synchronized? What are the cash flow and spread implications? Can the global delta of all publicly-traded options on an index like the S&P 500, Nikkei 225, and Euro Stoxx 500 be calculated? What are the market implications of delta’s ±0.5?

9. On a real-time basis, how much debt is outstanding in all forms (short term, long term, public, private)? What are the global, regional, national debt service burdens?

10. Can regular and random “event effects” (management change, economic leadership change, central bank policy change, ratings changes, earnings surprises, M&A, etc.) be anticipated and incorporated into investment strategies?

11. How effective are more recent instruments like ETFs and constraints such as sustainable and responsible investing (SRI)? Can big data spawn new generations of financial products?

12. How do big data methods and their presumed universal adoption by competitors alter the practice of corporate finance and asset management? In the end, does asset management bifurcate into short-term indexing and long-term active thematic styles?
Big data will come to be viewed as a key factor of production, if not the most important factor, in many industries. World economic growth likely will be quicker. In turn, the resulting implications for global capital markets are vast.

Presumably thanks to the guidance derived from new types of big data analyses and rejecting the “techno-pessimist thesis” of slowing advanced economy productivity in the early 21st century, resource use will become more efficient especially through the greater transparency fostered by such capabilities as dynamic real-time pricing. The location and intensity of goods and services production may be altered. New, higher-value, data-dependent products await introduction. Indeed, big data will come to be viewed as a key factor of production, if not the most important factor, in many industries. World economic growth likely will be quicker. In turn, the resulting implications for global capital markets are vast. Infrastructure construction, international capital flows, foreign exchange values, asset allocation, issuer selection, product innovation, and perhaps most important, economic and financial policies will hinge partially on the results of new big data methods.

THE GENESIS OF BIG DATA

Technology connectivity and new information are exploding. The printing press doubled medieval European knowledge over a 50-year period. A 50-fold knowledge increase now occurs about every 10 years. Assuming a world population of 10 billion in 2100 per the U.N. and a continued doubling of global information every two years, this implies at least a 2 to the 44th power increase in stored information over the remainder of the 21st century. This may sound unfathomable, but just imagine the recording of every e-mail, photo, video, Tweet, phone call, personal medical history, nearly every significant detail of an individual’s “life-logging,” and organization’s existence. And most meaningful bits of every legitimate commercial transaction also will be added to the global information set. This monumental data bulge will bear new costs. For example, the accessibility and accuracy of such information may be problematic and require “purification costs” and subscription fees.

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8 Rick Smolan and Jennifer Erwitt, The Human Face of Big Data (Sausalito, California: Against All Odds Productions, 2012).
Big data alone is not modern analytical alchemy. For instance, information without objectives can be near meaningless.

This information comes in two forms: structured data like familiar economic time series such as real GDP and a far greater volume of unstructured data like social media commentary on pertinent economic and market topics. Through time, some unstructured data will be converted into structured data. But the ratio of unstructured to structured data will remain high given the greater volume and velocity of unstructured data creation.

Individuals and large organizations may be overwhelmed by this rising information torrent. Recipients easily can spend much of their time in absorbing redundant and irrelevant data. This impedes the ability to search for new, more valuable discoveries and to engage in solution-seeking analyses. For example in capital markets, several dozen interpretations of the monthly U.S. employment report are probably unnecessary.

Big data alone is not modern analytical alchemy. For instance, information without objectives can be near meaningless. The number of ants on a sidewalk in Omaha, Nebraska, on July 19, 2025, likely has no significance beyond or even within entomology. The number of large versus small ships passing through the Panama Canal on this same July 19 versus the previous day could signal a possible shift in global trade flows.

**WHY NOW?**

Why the sudden buzz about big data when fact/information-based decision-making has been a best practice and management mantra for a very long time? In our view, the acceleration of the big data phenomenon over 2011-2013 reflects:

- migration of social interactions to the web and adoption of smaller-form, mobile factor computing like Tablets, Smartphones, and Ultrabooks. As a result, society is becoming more comfortable with online presence/lives leading to behavioral e-trails that can be mined/analyzed

- introduction of Cloud architecture: availability of large number of processors as well as network and storage capacity that can flex with changing workloads. This “just-in-time” capability leads to new possibilities for enterprises large and small

- massively parallel computing frameworks running on the Cloud architecture (e.g., Apache Hadoop) enable meaningful information extraction from extremely large datasets

- open source movement: community-driven free software tools used in information extraction, analysis, and dissemination that are on par or better than commercially available tools. Examples include Linux, Apache Hadoop, HBase, Mahout, and R. According to one estimate, the cost of developing these software tools currently exceeds $300 million and is growing

- greater availability of small, cheap, low-power sensors and networks allows the collection of vast amounts of previously uncollectable data

- visible success of Amazon’s and Netflix’s Recommendation Engines and Google’s advertising business has proven the value of extreme data analysis

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9 Structured data refers to data that is comprised of an organized collection of components, in which a relationship exists among the components of the collection. With unstructured data, no relationship exists among the components other than they belong to the same collection. See Nell Dale and Chip Weems, Turbo Pascal (London: Jones and Bartlett Publishers, 1995).

10 Amazon EC2, Google AppEngine, Microsoft Azure are examples of such publicly available Clouds.

11 Ohloh.
With the ascent of macroeconomics, increasing influence of central banks, and development of aggregate international economic and financial statistics, policymakers were able to devote their energies to more systemic issues.

The abundance of data in a variety of domains has also re-energized the scientific community. The return of denser neural networks, recent advancements in “deep” learning, semi-supervised learning, and significant progress in semantic technologies are harbingers of fascinating and accelerating developments in making machines smarter. Going further out, futurologist Ray Kurzweil has famously predicted “singularity” by 2029 when machine and human intelligence become equal.

**A “TRANSFORMATIONAL GROWTH” ERA FOR THE GLOBAL FINANCIAL SYSTEM**

Barter markets accompanied the rise of modern humanity more than 50 millennia ago. Financial markets arose concurrently with civilization some 50 centuries past. As shown in Exhibit 3, many of the objectives of modern financial markets were pioneered prior to the 20th century. With the ascent of macroeconomics, increasing influence of central banks, and development of aggregate international economic and financial statistics, policymakers were able to devote their energies to more systemic issues like economic stimulus, development, and risk mitigation.

Exhibit 3 – Capital Market Objectives

<table>
<thead>
<tr>
<th>Before the 19th Century</th>
<th>19th, 20th, 21st Centuries</th>
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<tr>
<td>Capital raising: channeling savings</td>
<td>Economic stimulus (Monetary Policy and Cyclical “Fiscal Accordion”)</td>
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<tr>
<td>Risk mitigation</td>
<td>Economic insurance</td>
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<td>Income smoothing</td>
<td>Economic development</td>
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<tr>
<td>Business expansion without tying up capital</td>
<td>Tax burden shifting</td>
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<tr>
<td>Liquidity creation</td>
<td>Systemic Risk Analyses and Mitigation</td>
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<tr>
<td></td>
<td>Stabilization and Positive Policy Promotion via World Bank, IMF, EIB, KFW, GSEs, IADB, ADB, SWFs, Municipal tax policy</td>
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<td></td>
<td>Globalization: International Division of Labor</td>
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The shock and aftermath of the Great Recession (2007-2015+) linger. Political, regulatory, and economic policymakers have sought to dampen the probability of recurrence through a major upgrade of the global financial system. This multi-faceted revamp is principally directed at de-risking, deleveraging, and attempting to downsize all corners of the global financial system in order to inhibit the transmission of inevitable downward financial market fluctuations including from too-big-to-fail clearing houses to the real economy.

12 The term, “Transformational Growth,” was coined by New School of Social Research economist, Edward Nell. This extension of the production possibility curve is vital for a dynamic capitalist economy.
Concurrently at approximately the midpoint of this “information age evolution,”
the creative reconfiguration of the world economic system seems to have accelerated
in accordance with the dictates of dynamic capitalism. A static economic system
eventually would implode. This reconfiguration is a highly familiar process. As far
back as 1925, John Moody the founder of the rating agency that bears his name
wrote, “The changes in methods of production and distribution which have been
going on in this country during the past fifty years have been so comprehensive
that an actual revolution in the methods of modern industrial society has been
taking place right before our eyes but with few of us realizing it.”  

What will be the implications of big data revolution for global financial and economic
environment? As visionary science fiction author Isaac Asimov wondered in I, Robot,
will the future global economy be managed by super computers where, “The Earth’s
economy is stable, and will remain stable, because it is based upon the decisions
of calculating machines […]”; and: “The population of Earth knows that there will be
no unemployment, no over-production or shortages. Waste and famine are words
in history books.” While such perfect machines might facilitate the analysis of
big data, can the fickle nature of economic decisions by humans be consistently
predicted as in Asimov’s psychohistory?

Asset management and the entire financial services industry are extensions of
the information and knowledge businesses, operating under a continuous state of
uncertainty. For example, the provision of classic bank loans, credit through debit
and charge cards, personal real estate mortgage credit (FICO scores), guarantees,
and manufacture and sale of credit securities demands a huge array of operating,
financial, management, and issue data. As evidenced by some of the striking
economic and credit market misfires since the mid-1970s, data and analytic
sufficiency may be wanting in some circumstances.

In practice, superior information can lead to, but does not guarantee, better
“evidence-based” rather than intuition-dependent decision-making by policymakers
and economic agents (see Bank of England’s Andy Haldane’s paper, “The Dog and
the Frisbee”). All techniques will be applied to anticipate the future as demonstrated
by the proliferating number of independent economic, sector, and issuer research
providers. The competitive pursuit of higher portfolio alpha might induce asset
managers to subscribe to practically any service, perhaps even a psychic, with a
record of forecasting prescience.

We believe big data will resculpt the asset management industry as portrayed in
Exhibit 4. New approaches will be required in research, analytics, asset allocation,
trading, and risk management. Through visualization-aided smart syntheses often
in the burgeoning era of “dashboards,” big data will expand the “assimilation range”
of even existing information by capital market professionals. New information
likely will inspire new vectors of innovation and lead to abandonment of “heuristic
aphorisms,” like “watch out for supply” that too often pass for analyses in the capital
markets. Policymakers also will respond to this new data, which will breed a cascade
of iterative feedback loops. As with any innovation, there will be constraints in the
form of real-time data quality, privacy/confidentiality, transmission speed,
overwhelming volumes, data scientist shortage, and security.

Fundamental equity and credit analyses likely will become even more granular in detail and lead to greater emphasis on issuer differentiation. With a steady stream of novel and higher quality inputs from big data, stock and bond markets may become less inclined to be as subservient to infrequent information lumps such as quarterly economic and corporate reports as shown in Exhibit 5. At the same time, the proliferation of new fundamental and tactical data points could escalate day-to-day choppiness as the markets sometimes struggle to differentiate between brief aberrations and the inception of new trends.
Economic releases such as GDP, inflation, and industrial production may become more accurate (subject to less revision) and less surprising thanks to advance signals propagated via big data methods. Key economic announcements like housing already can be reasonably anticipated by web crawlers. Greater economic, regional, national, and industry segmentations should be possible, with the most important drivers clearly delineated and accurately measured.

Galvanized as well by next-generation analytics (especially more rigorous time series, correlation, graphical, topological, and scenario analyses) and financial modeling methods, new information implies the congregation of asset management along three-already visible routes. First, information is the lifeblood of high-frequency algorithmic trading and the foundation of longer-term quantitative portfolio strategies. Second, richer information sets should enhance fundamental differentiation for traditional managers operating on medium-term horizons. Third, the practice of secular theme identification and capitalization will be enlivened by the data-based propagation of new market-moving conceptualizations about the future. To consider two possibilities, can demographically challenged economies generate high sustained growth rates through other factors of production like human capital enhancement? Should well-entrenched investment horizon constraints be rethought as in longer horizons and reduced constraints?

Moreover, we believe the intelligence garnered from big data techniques will have a profound influence on public and private sector users of capital markets as well as on consumers. For example, enhanced capital market knowledge will modify the operations of many organizations and especially their financial policies. In some more mature, highly competitive industries, big data promises further pricing power erosion given near-perfect price discovery and possibly lower barriers to entry. In turn, this will affect such core issuer decisions like capital spending, financial leverage, origination timing and structure selection, and dividend policy. Individual career and financial planning practices also will likely be altered in light of voluminous new information flows.

The complete market effects of this upgrade of the global financial system cannot be fully foretold in 2013. Unpredictable geopolitical events, like wars and terrorist activities, will still help govern the volatilities, correlations, and trajectories of capital market parameters. And big data alone will neither curb climate change nor speculative bursts of market optimism and pessimism, perhaps mainly driven by fluctuations in collective neurotransmitters.

In the aftermath of the Great Recession, regulators have been keen to expand their data collection and to pursue the creation of new metrics to monitor systemic well-being. In addition to augmenting transparency and efficiency, the availability of new data sets in the public domain should aid regulatory functions. Ironically, the well-intentioned drive for enhanced regulatory oversight in the Teens may be less significant in the long run than the arrival of big data. This gush of information should lead to a reduction of systemic uncertainty and known macro-prudential and micro-prudential risk mitigation.

But as with most technological progress, transition side effects usually become manifest. In ever more efficient markets, real alpha may become scarcer for portfolio managers. The exponential generation of new information currents will trigger an even greater demand for “model compression” into usable decision-making components. As with all financial market models dependent on information shaped by occasionally irrational human emotions, subsequent reality may diverge sharply from ex-ante predictions. And certain portfolio management methodologies, already clustering along “beta trails” in the form of indexing and ETFs at the expense of issuer differentiation, may become more common. Traditional risks, like constrained awareness of excess financial leverage, will fade in potential systemic malfeasance compared to new risks like data highways’ disruption (perhaps via cyber attacks).
The technological, analytical, and information innovations of the 20th century both transformed and preserved the core goal of the asset management profession. The cardinal objective of risk-adjusted return optimization under uncertainty did not migrate; the path did. For example, the arrival of mainframe computers in the 1950s and then personal computers in the 1980s unfortunately have not repealed the vicissitudes of business cycles, sovereign and industry misfortunes, poor performances by individual issuers and less-than-perfect foresight by financial decision makers. Indeed, technology and primitive analytics arguably enabled some of the most spectacular meltdowns like the U.S. thrift crisis in the mid-to-late 1980s and Long-Term Capital Management in 1998.

So too, the innovations and challenges of the 21st century will not entirely amend the basic mission of asset management (Exhibit 6) to enhance and to preserve wealth for an assumed level of risk within a complex global capital market framework. As always in a dynamic capitalist system, business methods, in this case asset management strategies depicted in Exhibit 7, will change through time. Fast innovators fueled by big data-inspired creativity have an advantage over slow movers. Non-responders may be headed toward obsolescence. Consider the mammoth bond and equity indexes, in some ways the original big data capital market tool. Thanks to the greater ability to blend issuer fundamental information with all cash/derivative debt and equity prices, absolute and relative value issuer rankings have become more precise.

Exhibit 6 – Global Asset Management Mission: Preserve and Enhance Wealth for a Given Level of Risk

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<tr>
<th>Late 20th/Early 21st Century Global Capital Market Framework</th>
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<td>– The Great Recession of 2007-2015 will be recalled for “systematic credit cleansing; a secular adjustment in credit risk premia and credit market methodology”</td>
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<th>Global Asset Management Developments</th>
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<tr>
<td>Low yields, paltry AE growth</td>
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<td>Aging AE demographics</td>
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<td>Global Grand Convergence</td>
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<tr>
<td>EM mainstreaming</td>
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<td>GPR rise</td>
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<td>Globalization/deceleration</td>
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<th>Global Portfolio Strategy</th>
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<tr>
<td>Moving out risk horizon curve; portfolio concentration; minimization of pro-cyclical processes; model standardization</td>
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<tr>
<td>Opportunities in IG and HY credit, EM, Frontier, real estate, and Alternative markets</td>
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* Quadruple A’s: alternatives; absolute return; alpha/beta separation; all styles, geographies on choice menu; † Quadruple I’s: innovation; infrastructure; inflation-protection; insurance of risk

Source: BNY Mellon Center for Global Investment and Market Intelligence
Financial system data can be abused in the pursuit of knowingly or inadvertently asserting false claims.

“A FEW CAVEATS

“Not everything that can be counted counts, and not everything that counts can be counted.” — Albert Einstein

“Data-driven predictions can succeed, and they can fail. It is when we deny our role in the process that the odds of failure rise. Before we can demand more of our data, we need to demand more of ourselves.” — Nate Silver

Even for enthusiastic proponents like us, the big data revolution should be viewed in a realistic light. Big data will help but will not solve all problems. The ongoing upgrade of the global financial system will be enhanced but not completely defined by big data. And shown in Exhibit 8, financial system data can be abused in the pursuit of knowingly or inadvertently asserting false claims.

Ultimately, a combination of a new generation of cross-trained programmers, data scientists, operating managements, financial managements, and/or someday with sentient computers will seek to optimize big data pursuits.

CONCLUSION: “GLIMPSE OF A BRIGHTER FUTURE”

As has been the case since the Middle Ages, a more technologically diverse and consumption-driven financial system awaits. An older and densely populated world will cluster in megacities, perhaps too close to rising seas in some geographies. Real-time pricing will pertain to all markets, with the application of sophisticated statistical analysis. A globally connected marketplace with enhanced information flows will generate almost perfectly steady correlations among economic/financial variables. Financial diversification will become less efficient and encourage more portfolio concentration. Assuming political stability, frontier markets, where a Mongolia becomes the next Taiwan, may become less reliable alpha generators.
These evolutionary forces will be amplified by big data to recast institutional, organizational, and personal behaviors, and in the course of economic development, hopefully will upgrade and improve the efficacy of the global financial system in our opinion.

The transformational effects of big data will extend far beyond the economic and financial realms. Deep questions will be spawned about the ownership, public access, and use of vital data sets. And as long predicted and recently witnessed, big data results may kindle geopolitical risk shifts and weaken the sovereign authority of some nations.

There’s so much yet to discover across all fields, especially in the sciences, economics, and capital markets. Big data will not trigger nor answer all questions and is not the Holy Grail to perpetual financial system bliss. Stewards of big data enterprises need to transition from more of a warehousing mindset to an open system that fosters a high volume of research inquiry. The main impediment to the maximization of big data methods may be limited imagination and failure to embrace consilience among multiple disciplines in framing and rewarding big data research projects.

As with any new field, the conceptualization and practices of big data will evolve rapidly in not always predictable directions. For example, the term “big data” might be unbundled into a myriad of “classification flavors” like very big data, big data, medium data, and small data based on the volume of data. The same holds for analytics: heavy analytics, medium analytics, small analytics, and little or no analytics. A similar scheme could be engineered for external data sifting and visualization. See Exhibit 9 for a hypothetical classification of big data problems in asset management.

### Exhibit 9 – Classification of “Big Data Problems”

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<tr>
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<th>Heavy Analytics</th>
<th>Medium Analytics</th>
<th>Small Analytics</th>
<th>Little or No Analytics</th>
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<tbody>
<tr>
<td><strong>Very Big Data</strong></td>
<td>World Economic and Financial Markets Scenario Analysis</td>
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<td><strong>Big Data</strong></td>
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<td>Multi-asset Class Return Attribution</td>
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<td><strong>Medium Data</strong></td>
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<td>Ranking Financials of Issuers in Corporate Sectors as in Finance</td>
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<td><strong>Small Data</strong></td>
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<td>Mapping Relative Performance of a Fund or Portfolio to an Index</td>
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</table>

Source: BNY Mellon Center for Global Investment and Market Intelligence.
The advancing utilization of big data methods in the early 21st century will be recalled as a “Very Big Plus” for the global financial system. In our opinion, the advent of the big data era will join the ranks of the other major positive “Great Disruptors,” shown in Exhibit 10, in shaping a healthier and more prosperous future for the global financial system and its billions of dependent users.

Exhibit 10 – “The Great Disruptors”
Technological Progress and Major Political Events: 10,000 BC to 2100

Dates mainly pertain to initial proof of concept and/or practical or commercial application.

Source: BNY Mellon using sources from our bibliography (As of April 22, 2013).
BIBLIOGRAPHY


Cox, M., and David Ellsworth. “Application-Controlled Demand Paging for Out-of-Core Visualization.” 8th Conference on Visualization ’97 (October 18-24, 1997).


DeCovny, Sherree. “Next-Generation Analytics.” CFA Digest (July/August 2012).


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