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1. Mapping global data: Growth and value creation

Many of the most powerful inventions throughout human history, from language to the modern computer, were those that enabled people to better generate, capture, and consume data and information. We have witnessed explosive growth in the amount of data in our world. Big data has reached critical mass in every sector and function of the typical economy, and the rapid development and diffusion of digital information technologies have intensified its growth.

We estimate that new data stored by enterprises exceeded 7 exabytes of data globally in 2010 and that new data stored by consumers around the world that year exceeded an additional 6 exabytes. To put these very large numbers in context, the data that companies and individuals are producing and storing is equivalent to filling more than 60,000 US Libraries of Congress. If all words spoken by humans were digitized as text, they would total about 5 exabytes--less than the new data stored by consumers in a year. The increasing volume and detail of information captured by enterprises, together with the rise of multimedia, social media, and the Internet of Things will fuel exponential growth in data for the foreseeable future.

There is no doubt that the sheer size and rapidly expanding universe of big data are phenomena in themselves and have been the primary focus of research thus far. But the key question is what broader impact this torrent of data might have. Many consumers are suspicious about the amount of data that is collected about every aspect of their lives, from how they shop to how healthy they are. Is big data simply a sign of how intrusive society has become, or can big data, in fact, play a useful role in economic terms that can benefit all societal stakeholders?

The emphatic answer is that data can indeed create significant value for the world economy, potentially enhancing the productivity and competitiveness of companies and creating a substantial economic surplus for consumers and their governments. Building on MGI's deep background in analyzing productivity and competitiveness around the world, this research explores a fresh linkage between data and productivity. Although the relationship between productivity and IT investments is well established, exploring the link between productivity and data breaks new ground. Based on our findings, we believe that the global economy is on the cusp of a new wave of productivity growth enabled by big data.

In this chapter, we look at past and current research on sizing big data and its storage capacity. We then explore the likely relationship between big data and productivity, drawing on past analyses of the impact of IT investment and innovation to drive productivity that we believe is directly applicable to the current and likely future evolution of big data.

THE VOLUME OF DATA IS GROWING AT AN EXPONENTIAL RATE

MGI is the latest of several research groups to study the amount of data that enterprises and individuals are generating, storing, and consuming throughout the global economy. All analyses, each with different methodologies and definitions, agree on one fundamental point--the amount of data in the world has been expanding rapidly and will continue to grow exponentially for the foreseeable future (see Box 3, "Measuring data") despite there being a question mark over how much data we, as human beings, can absorb (see Box 4, "Human beings may have limits in their ability to consume and understand big data" on page 18).

Hal Varian and Peter Lyman at the University of California Berkeley were pioneers in the research into the amount of data produced, stored, and transmitted. As part of their "How much information?" project that ran from 2000 to 2003, the authors estimated that 5 exabytes of new data were stored globally in 2002 (92 percent on magnetic media) and that more than three times that amount--18 exabytes--of new or original data were transmitted, but not necessarily stored, through electronic channels such as telephone, radio, television, and the Internet. Most important, they estimated that the amount of new data stored doubled from 1999 to 2002, a compound annual growth rate of 25 percent.

Then, starting in 2007, the information-management company EMC sponsored the research firm IDC to produce an annual series of reports on the "Digital Universe" to size the amount of digital information created and replicated each year. This analysis showed that in 2007, the amount of digital data created in a year exceeded the world's data storage capacity for the first time. In short, there was no way to actually store all of the digital data being created. They also found that the rate at which data generation is increasing is much faster than the world's data storage capacity is expanding, pointing strongly to the continued widening of the gap between the two. Their analysis estimated that the total amount of data created and replicated in 2009 was 800 exabytes--enough to fill a stack of DVDs reaching to the moon and back. They projected that this volume would grow by 44 times to 2020, an implied annual growth rate of 40 percent.

Most recently, Martin Hilbert and Priscila López published a paper in Science that analyzed total global storage and computing capacity from 1986 to 2007. Their analysis showed that while global storage capacity grew at an annual rate of 23 percent over that period (to more than 290 exabytes in 2007 for all analog and digital media), general-purpose computing capacity, a measure of the ability to generate and process data, grew at a much higher annual rate of 58 percent. Their study also documented the rise of digitization. They estimated that the percentage of data stored in digital form increased from only 25 percent in 2000 (analog forms such as books, photos, and audio/video tapes making up the bulk of data storage capacity at that time) to a dominant 94 percent share in 2007 as media such as hard drives, CDs, and digital tapes grew in importance (Exhibits 5 and 6).

THE INTENSITY OF BIG DATA VARIES ACROSS SECTORS BUT HAS REACHED CRITICAL MASS IN EVERY SECTOR

There is broad agreement that data generation has been growing exponentially. Has that growth been concentrated only in certain segments of the global economy? The answer to that question is no. The growth of big data is a phenomenon that we have observed in every sector. More important, data intensity--i.e., the average amount of data stored per company--across sectors in the global economy is sufficient for companies to use techniques enabled by large datasets to drive value (although some sectors had significantly higher data intensity than others). Business leaders across sectors are now beginning to ask themselves how they can better derive value from their data assets, but we would argue that leaders in sectors with high data intensity in particular should make examining the potential a high priority.

MGI estimates that enterprises around the world used more than 7 exabytes of incremental disk drive data storage capacity in 2010; nearly 80 percent of that total appeared to duplicate data that had been stored else where. We also analyzed data generation and storage at the level of sectors and individual firms. We estimate that, by 2009, nearly all sectors in the US economy had at least an average of 200 terabytes of stored data per company (for companies with more than 1,000 employees) and that many sectors had more than 1 petabyte in mean stored data per company. Some individual companies have far higher stored data than their sector average, potentially giving them more potential to capture value from big data.

Some sectors Exhibit far higher levels of data intensity than others, implying that they have more near-term potential to capture value from big data. Financial services sectors, including securities and investment services and banking, have the most digital data stored per firm on average. This probably reflects the fact that firms involved in these sectors tend to be transaction-intensive (the New York Stock Exchange, for instance, boasts about half a trillion trades a month) and that, on average, these types of sectors tend to have a preponderance of large firms. Communications and media firms, utilities, and government also have significant digital data stored per enterprise or organization, which appears to reflect the fact that such entities have a high volume of operations and multimedia data. Discrete and process manufacturing have the highest aggregate data stored in bytes. However, these sectors rank much lower in intensity terms, since they are fragmented into a large number of firms. Because individual firms often do not share data, the value they can obtain from big data could be constrained by the degree to which they can pool data across manufacturing supply chains (see chapter 3d on manufacturing for more detail) (Exhibit 7).

In addition to variations in the amount of data stored in different sectors, the types of data generated and stored--i.e., whether the data encodes video, images, audio, or text/numeric information--also differ markedly from industry to industry. For instance, financial services, administrative parts of government, and retail and wholesale all generate significant amounts of text and numerical data including customer data, transaction information, and mathematical modeling and simulations (Exhibit 8). Other sectors such as manufacturing, healthcare, and communications and media are responsible for higher percentages of multimedia data. Manufacturing generates a great deal of text and numerical data in its production processes, but R&D and engineering functions in many manufacturing subsectors are heavy users of image data used in design.

Image data in the form of X-rays, CT, and other scans dominate data storage volumes in health care. While a single page of records can total a kilobyte, a single image can require 20 to 200 megabytes or more to store. In the communications and media industries, byte-hungry images and audio dominate storage volumes. Indeed, if we were to examine pure data generation (rather than storage), some subsectors such as health care and gaming generate even more multimedia data in the form of real-time procedure and surveillance video, respectively, but this is rarely stored for long.

Turning to a geographic profile of where big data are stored, North America and Europe together lead the pack with a combined 70 percent of the global total currently. However, both developed and emerging markets are expected to experience strong growth in data storage and, by extension, data generation at rates of anywhere between 35 and 45 percent a year. An effort to profile the distribution of data around the world needs to take into account that data are not always stored in the country where they are generated; data centers in one region can store and analyze data generated in another.

MAJOR ESTABLISHED TRENDS WILL CONTINUE TO DRIVE DATA GROWTH

Across sectors and regions, several cross-cutting trends have fueled growth in data generation and will continue to propel the rapidly expanding pools of data. These trends include growth in traditional transactional databases, continued expansion of multimedia content, increasing popularity of social media, and proliferation of applications of sensors in the Internet of Things.

Enterprises are collecting data with greater granularity and frequency, capturing every customer transaction, attaching more personal information, and also collecting more information about consumer behavior in many different environments. This activity simultaneously increases the need for more storage and analytical capacity. Tesco, for instance, generates more than 1.5 billion new items of data every month. Wal-Mart's warehouse now includes some 2.5 petabytes of information, the equivalent of roughly half of all the letters delivered by the US Postal Service in 2010.

The increasing use of multimedia in sectors including health care and consumer-facing industries has contributed significantly to the growth of big data and will continue to do so. Videos generate a tremendous amount of data. Every minute of the now most commonly used high-resolution video in surgeries generates 25 times the data volume (per minute) of even the highest resolution still images such as CT scans, and each of those still images already requires thousands of times more bytes than a single page of text or numerical data. More than 95 percent of the clinical data generated in health care is now video. Multimedia data already accounts for more than half of Internet backbone traffic (i.e., the traffic carried on the largest connections between major Internet networks), and this share is expected to grow to 70 percent by 2013.

The surge in the use of social media is producing its own stream of new data. While social networks dominate the communications portfolios of younger users, older users are adopting them at an even more rapid pace. McKinsey surveyed users of digital services and found a 7 percent increase in 2009 in use of social networks by people aged 25 to 34, an even more impressive 21 to 22 percent increase among those aged 35 to 54, and an eye-opening 52 percent increase in usage among those aged 55 to 64. The rapid adoption of smartphones is also driving up the usage of social networking (Exhibit 9). Facebook's 600 million active users spend more than 9.3 billion hours a month on the site--if Facebook were a country, it would have the third-largest population in the world. Every month, the average Facebook user creates 90 pieces of content and the network itself shares more than 30 billion items of content including photos, notes, blog posts, Web links, and news stories. YouTube says it has some 490 million unique visitors worldwide who spend more than 2.9 billion hours on the site each month. YouTube claims to upload 24 hours of video every minute, making the site a hugely significant data aggregator. McKinsey has also documented how the use of social media and Web 2.0 has been migrating from the consumer realm into the enterprise.

Increasing applications of the Internet of Things, i.e., sensors and devices embedded in the physical world and connected by networks to computing resources, is another trend driving growth in big data.

McKinsey research projects that the number of connected nodes in the Internet of Things--sometimes also referred to as machine-to-machine (M2M) devices--deployed in the world will grow at a rate exceeding 30 percent annually over the next five years (Exhibit 10). Some of the growth sectors are expected to be utilities as these operators install more smart meters and smart appliances; healthcare, as the sector deploys remote health monitoring; retail, which will eventually increase its use of radio frequency identification (RFID) tags; and the automotive industry, which will increasingly install sensors in vehicles.

TRADITIONAL USES OF IT HAVE CONTRIBUTED TO PRODUCTIVITY GROWTH-- BIG DATA IS THE NEXT FRONTIER

The history of IT investment and innovation and its impact on competitiveness and productivity strongly suggest that big data can have similar power to transform our lives. The same preconditions that enabled IT to power productivity are in place for big data. We believe that there is compelling evidence that the use of big data will become a key basis of competition, underpinning new waves of productivity growth, innovation, and consumer surplus--as long as the right policies and enablers are in place.

Over a number of years, MGI has researched the link between IT and productivity. The same causal relationships apply just as much to big data as they do to IT in general. Big data levers offer significant potential for improving productivity at the level of individual companies. Companies including Tesco, Amazon, Wal-Mart, Harrah's, Progressive Insurance, and Capital One, and Smart, a wireless player in the Philippines, have already wielded the use of big data as a competitive weapon--as have entire economies (see Box 5, "Large companies across the globe have scored early successes in their use of big data").

We can disaggregate the impact of IT on productivity first into productivity growth in IT-producing sectors such as semiconductors, telecoms, and computer manufacturing, and that of IT-using sectors. In general, much of the productivity growth in IT-producing sectors results from improving the quality of IT products as technology develops. In this analysis, we focus largely on the sectors that use IT (and that will increasingly use big data), accounting for a much larger slice of the global economy than the sectors that supply IT.

Research shows that there are two essential preconditions for IT to affect labor productivity. The first is capital deepening--in other words, the IT investments that give workers better and faster tools to do their jobs. The second is investment in human capital and organizational change--i.e., managerial innovations that complement IT investments in order to drive labor productivity gains. In some cases, a lag between IT investments and organizational adjustments has meant that productivity improvements have taken awhile to show up. The same preconditions that explain the impact of IT in enabling historical productivity growth currently exist for big data.

There have been four waves of IT adoption with different degrees of impact on productivity growth in the United States (Exhibit 11). The first of these eras--the "mainframe" era--ran from 1959 to 1973. During this period, annual US productivity growth overall was very high at 2.82 percent. IT's contribution to productivity was rather modest; at that stage, IT's share of overall capital expenditure was relatively low. The second era from 1973 to 1995, which we'll call the era of "minicomputers and PCs," experienced much lower growth in overall productivity, but we can attribute a greater share of that growth to the impact of IT. Significant IT capital deepening occurred. Companies began to boost their spending on more distributed types of computers, and these computers became more powerful as their quality increased.

The third era ran from 1995 to 2000--the era of the "Internet and Web 1.0." In this period, US productivity growth returned to high rates, underpinned by significant IT capital deepening, an intensification of improvements in quality, and also the diffusion of significant managerial innovations that took advantage of previous IT capital investment. As we have suggested, there as a lag between IT investment and the managerial innovation necessary to accelerate productivity growth. Indeed, although we have named this era for the investments in Internet and Web 1.0 made at this time, most of the positive impact on productivity in IT-using sectors came from managerial and organizational change in response to investments in previous eras in mainframe, minicomputers, and PCs--and not from investment in the Internet.

MGI research found that in this third era, productivity gains were unevenly distributed at the macroeconomic, sector, and firm levels. In some cases, a leading firm that had invested in sufficient IT was able to deploy managerial innovation to drive productivity and outcompete its industry counterparts. Wal-Mart's implementation of IT-intensive business processes allowed the company to outperform competitors in the retail industry. Eventually those competitors invested in IT in response, accelerated their own productivity growth, and boosted the productivity of the entire sector.

In fact, MGI found that six sectors accounted for almost all of the productivity gains in the US economy, while the rest contributed either very little productivity growth or even, in some cases, negative productivity growth. The six sectors that achieved a leap in productivity shared three broad characteristics in their approach to IT. First, they tailored their IT investment to sector-specific business processes and linked it to key performance levers. Second, they deployed IT sequentially, building capabilities overtime. Third, IT investment evolved simultaneously with managerial and technical innovation.

The fourth and final era, running from 2000 to 2006, is the period of the "mobile devices and Web 2.0." During this period, the contribution from IT capital deepening and that from IT-producing sectors dropped. However, the contribution from managerial innovations increased--again, this wave of organizational change looks like a lagged response to the investments in Internet and Web 1.0 from the preceding five years.

What do these patterns tell us about prospects for big data and productivity? Like previous waves of IT-enabled productivity, leveraging big data fundamentally requires both IT investments (in storage and processing power) and managerial innovation. It seems likely that data intensity and capital deepening will fuel the diffusion of the complementary managerial innovation boost productivity growth. As of now, there is no empirical evidence of a link between data intensity or capital deepening in data investments and productivity in specific sectors. The story of IT and productivity suggests that the reason for this is a time lag and that we will, at some point, see investments in big-data-related capital deepening pay off in the form of productivity gains.

In the research we conducted into big data in five domains across different geographies, we find strong evidence that big data levers can boost efficiency by reducing the number or size of inputs while retaining the same output level. At the same time, they can be an important means of adding value by producing more real output with no increase in input. In health care, for example, big data levers can boost efficiency by reducing systemwide costs linked to undertreatment and overtreatment and by reducing errors and duplication in treatment. These levers will also improve the quality of care and patient outcomes. Similarly, in public sector administration, big data levers lead to not only efficiency gains, but also gains in effectiveness from enabling governments to collect taxes more efficiently and helping to drive the quality of services from education to unemployment offices. For retailers, big data supply chain and operations levers can improve the efficiency of the entire sector. Marketing and merchandising levers will help consumers find better products to meet their needs at more reasonable prices, increasing real value added.

The combination of deepening investments in big data and managerial innovation to create competitive advantage and boost productivity is very similar to the way IT developed from the 1970s onward. The experience of IT strongly suggests that we could be on the cusp of a new wave of productivity growth enabled by the use of big data.

Data have become an important factor of production today--on a par with physical assets and human capital--and the increasing intensity with which enterprises are gathering information alongside the rise of multimedia, social media, and the Internet of Things will continue to fuel exponential growth in data for the foreseeable future. Big data have significant potential to create value for both businesses and consumers.