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When “Bits” Meet “Atoms”: Implications of the Second Machine Age for Corporate Profitability and Traditional Business Models



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- Although the impact of the Second Machine (or Digital) Age was difficult to see for the first few decades, as even exponential growth from a small base is not visible for a long time, we believe technological innovation reached an inflection point around 2007.
- The Digital Age and the transition from “atoms” to “bits” implies a capital-light economy in which technology is being substituted for labor and physical assets. This points to higher ROE—in fact, all three components should rise (profit margins, asset utilization and leverage).
- Since progress in the Digital Age is exponential rather than linear, the business world has never seen disruption at this speed and scale before: witness the dramatic transformation in industries such as newspaper, film, music, telecommunications, retail, transportation, and accommodation.
- Additionally, platforms are arguably the best business models ever created, benefiting from low marginal costs, with their distinctive asset-light nature and powerful network effects. Winner-takes-all dynamics have resulted in neo-monopoly profits for dominant firms and increased concentration in most sectors.
- Moreover, the pace of technological change continues to accelerate, suggesting we are nowhere near the late stages of this transformation.
- The ability of companies to generate free cash flows is becoming increasingly dependent on how they adapt their business models to the Digital Age. We believe companies that can consistently generate free cash flow and allocate it competently will provide investors with the best returns.

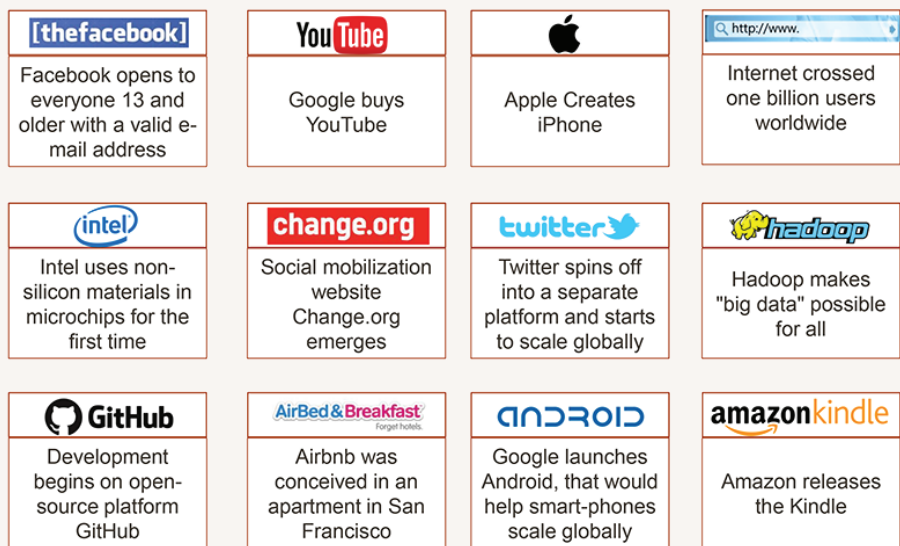
I. The Big Picture

By fundamentally improving the design of the steam engine in 1781, the inventor James Watt helped unleash the beginning of the Industrial Revolution and the First Machine Age. Prior to that time, economic growth was largely powered by human and animal muscle. Economic historians claim this transformation marked the most important event in the history of humanity since the domestication of animals and plants.

The Second Machine Age, which has also been called the Digital Age, commenced with the shift from mechanical and analogue electronic technology to digital electronics which began in the late 1950s. The importance of this transformation was highlighted in 1965

The Digital Age entered the second half of the chessboard ten years ago.

FIGURE 1: What the Hell Happened in 2007?



Source: Thank You For Being Late, Thomas L. Friedman, 2016

by Gordon Moore, who later founded Intel. He believed there would be (at least for a while) an exponential relationship between integrated circuit complexity and time. Although he never stated this verbatim, Moore’s Law has come to imply that integrated circuits would double in performance roughly every 18 months. However, the impact of the Digital Age was difficult to see for the first few decades as “doubling” from a small base is not visible for a long time.

To illustrate that point, let’s borrow a well-known story from the futurist Ray Kurzweil. Once upon a time, in the 9th century, the Emperor of India asked his subjects to come up with a new game. One clever subject obliged, and the result was the game of “chess,” which the Emperor enjoyed tremendously. The monarch asked how he would like to be rewarded and the subject replied that he only wanted a few grains of rice to feed his family, suggesting the Emperor could use the chessboard to determine the amount. The clever inventor proposed placing one grain of rice on square one, two on square 2, four on square 3 and so on—a doubling of the amount on each additional square. There are 64 squares on a chessboard, and one finds that after 32 doubles, there are roughly four billion grains of rice. That is a large amount,

but conceivable to most of us. However, after 64 squares, the sum is greater than all the rice that has ever been produced in the world. Needless to say, once he figured this out, the Emperor was not amused and lost his temper (and in some versions of the fable, the subject lost his head). Regardless, the story serves to illustrate the power of exponential growth, which is barely noticed

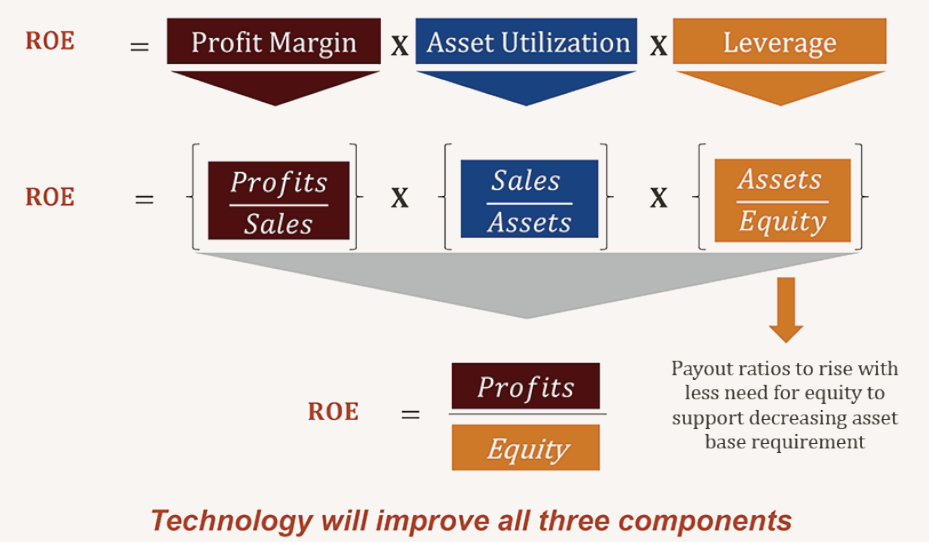
at first, but soon becomes overwhelming in a way that linear processes can never be.

This story led us to wonder when the Digital Age entered the back half of the chessboard. If it began in, say, the late-1950s, and processing power doubles every 18 months, then we can think of it landing on the 33rd square of the board around 2007. And look at what happened that year (Figure 1). This list is taken from a chapter in Thomas Friedman’s book, *Thank You For Being Late*. In many ways, 2007 was the year when the power of exponential growth became evident, with the Digital Age’s impact becoming visibly clear to many of us.

A second narrative to illustrate the power of exponential growth comes from “Rise of the Robots” by Martin Ford. He asks us to imagine getting into our car and starting to drive at 5 miles per hour. After a minute, we double our speed to 10 mph, drive for another minute, double our speed again, and so on. In the first minute, we would travel 440 feet. In the third minute at 20 mph, we’d cover 1,760 feet. In the fifth minute, speeding along at 80 mph, we’d go well over a mile. To complete the sixth minute, he suggests we’d need a faster car—as well as a racetrack. Now think about how fast we would be traveling in the twenty-eighth minute (approaching the second half of the chessboard). We would be cruising

Most companies are replacing labor and assets with technology, adopting “asset light” business models.

FIGURE 2: The Digital Age is Positive for all Three Components of ROE



along at 671 million mph and in that minute would travel more than 11 million miles. Five minutes or so at that speed would get you to Mars. Martin Ford suggests that is where technology stands today, relative to when the first primitive integrated circuits started plodding along in the late 1950s.

Atoms Represented the First Machine Age Whereas Bits Represent the Digital Age

The exponential growth of processing power, as aptly expressed by Moore’s Law, has helped drive the digitization of information. This data is composed of “bits,” not “atoms.” Bits represent the Digital Age whereas Atoms represented the First Machine Age. The key differentiating point is that data in the form of bits can be copied freely, perfectly and instantaneously. As such, they are usable over and over again, unlike goods constructed from atoms.

The old saying, “you cannot have your cake and eat it, too,” speaks to the world of atoms. Economists use the term “rivalrous” consumption to describe such goods. If there is a glass of water on the table, only one of us can drink it. On the other hand, a “bit” of information is “non-rivalrous,” as it can be consumed or reused over and over again. This and other related properties of the Digital Age have important implications for the structure of the economy and traditional business models. This includes, most crucially, higher margins and profits for the relatively small number of dominant firms.

The impact of the Digital Age on profits and margins is best viewed through the DuPont Return on Equity equation (Figure 2). It shows how the product of profit margin, asset utilization and leverage determines a firm’s profitability (this assumes a fiction: accounting is truthful and accurate, and accrual policies are consistent across all firms).

Beginning with profit margins, as firms substitute technology for labor, their profit margins will rise (assuming revenues are constant which, lamentably, will be a challenge for many firms in a winner-takes-all economy). Further, if a company substitutes technology for assets, its asset utilization will rise. The product of these two ratios gives us the return on assets employed in

the business. If the company has no debt in any form, this will be equal to return on equity. However, most firms possess some level of debt as assets rarely equal equity on a company’s balance sheet.

If a company determines that it does not need the same level of assets to run its business as it did in the past, say because technology has replaced the need for “atoms” (people and fixed assets), it can remove “equity” from the business through cash dividends, share buybacks, or debt pay downs. This follows from the observed trend toward “asset light” business models. The “atoms” of human beings and fixed tangible assets are being replaced by “bits” of technology and intangible assets. This effect is appearing in almost every company we examine as it endeavors to become more efficient in its use of labor and assets. Any firm not pursuing an “asset light” model faces obsolescence, as rivals will compete its business away.

II. Some Illustrative Cases

Disruptive Innovation: Turbocharged by the Digital Age

The business world has never seen disruption at this pace and breadth before. Although there have been other highly disruptive General Purpose Technologies (for example, the steam engine from 1781 and electricity a century later), their progress was linear rather than exponential.

We now provide a few examples to illustrate the pace and breadth of the disruptive impact from the Digital Age.

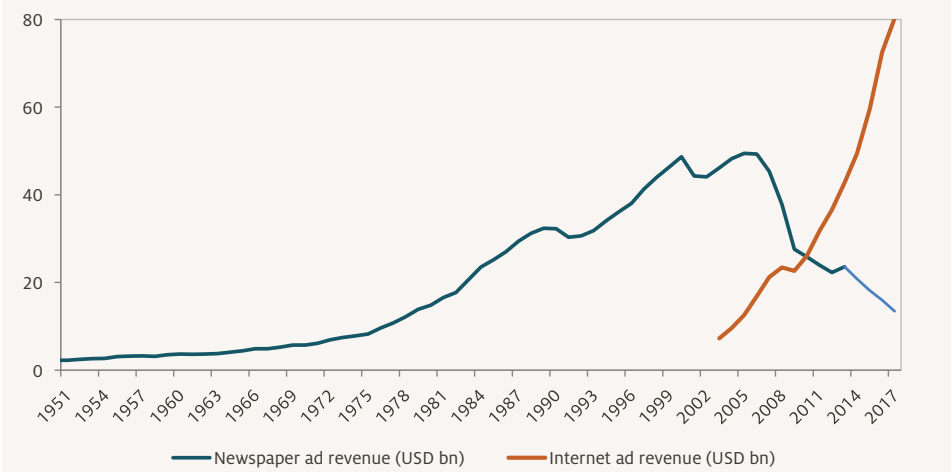
In 2006, the U.S.’s 2,400 newspapers generated almost \$50 billion of advertising revenues. However, within a decade these revenues had declined by 70% and are expected to continue to decline by 15% annually over the next five years (Figure 3). On the other hand, internet ad revenues have been growing by 20% annually, with Google and Facebook being the big winners (their digital ad revenues are up tenfold since 2001). When it comes to advertising revenues, “bits crushed atoms.”

Photography provides a second example of this disruptive process. Film was a substantial \$10 billion industry in 1997. However, the share of consumption expended on film and photographic supplies has declined by 80% over the last two decades (Figure 4). Echoing this, in 1997, Kodak’s stock market value reached an all-time high of just over \$30 billion. Fifteen years later, Kodak declared bankruptcy. Film in the form of “atoms” lost out to that in the form of “bits.”

Next, the global music industry has been forced to dramatically change its economic model over the last decade or so. Worldwide sales of recorded music declined by roughly 50% from \$24 billion in 1999 to just over \$12 billion in 2014, with a massive transition from physical to

Disruptive technology has hit the newspaper industry’s ad revenue extremely hard.

FIGURE 3: Advertising Revenues of U.S. Newspapers vs. Internet



Source: Bloomberg, Newspaper Association of America, Magnaglobal, PwC, Epoch Investment Partners

digital (**Figure 5**). In 2014, the global music industry generated roughly equal amounts of revenue from digital channels as from physical formats such as CDs. However, we estimate digital sales will be five times that of physical sales by 2021. “Bits” crushed “atoms” yet again.

A final example is provided by the telecommunications industry. In 2000, U.S. households spent \$77 billion on long distance calls. In 2013, that amount had declined to less than \$16 billion and today is much lower still. Further illustrations could be provided for the retail sector (being disrupted by Amazon), broadcast media (Netflix), transportation (Uber), accommodation (Airbnb), and so on. All this serves to demonstrate that digital technologies are the most powerful tools (weapons) ever wielded by disruptors. We now examine what this means for the microeconomics of business profits, and then for corporate earnings at the macro level.

III. The Microeconomics

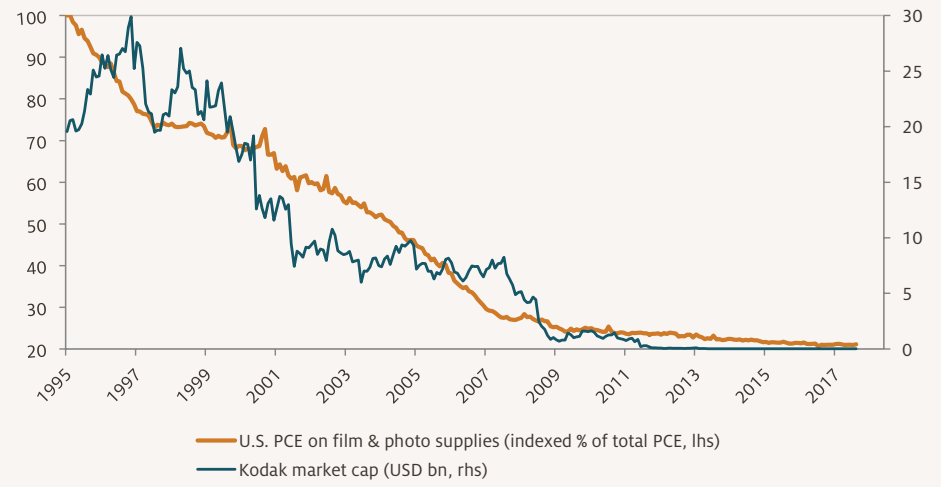
Copying Digital Goods: Free, Perfect and Instantaneous

Information goods once digitized can be copied for “free,” with the digital copies being “perfect” duplicates of the original. Further, their distribution is almost “instantaneous,” thanks to the modern internet. Free, perfect and instantaneous are the hallmarks of digital disruptive strategies. Traditional goods and services are at a huge disadvantage since they do not possess these qualities. Further, with cloud computing, AI and machine learning, more data translates to a smarter, more effective platform.

A digital platform can be characterized by near zero marginal cost of access, duplication, and distribution. Common digital platforms include Amazon, Netflix, Google’s search engine, Facebook, the iPhone’s app store, Spotify, Uber, and Airbnb. They all feature business models with high fixed costs and low marginal costs, which are the key attributes of natural monopolies. (The most common examples prior to the Digital Age were utilities and telecoms.) This helps explain why we’ve observed neo-monopoly profits for the dominant platform firms, as well

The Digital Age also wreaked havoc on the film industry.

FIGURE 4: Kodak’s Market Cap and Consumer Spending on Film

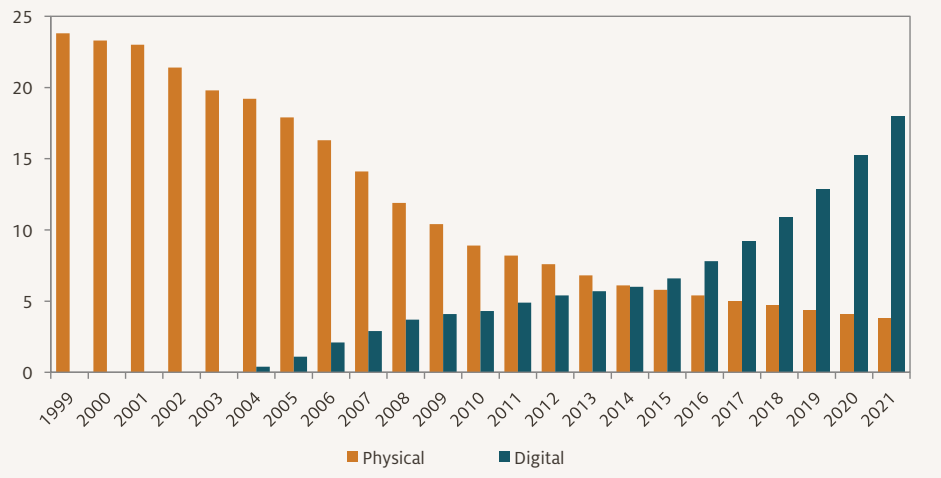


Source: Bloomberg, Epoch Investment Partners

Note: Orange line shows personal consumption expenditures on film and photographic supplies as a percentage of total personal consumption expenditures, indexed to 100 in 1995.

The transition from atoms to bits has been challenging for the music industry.

FIGURE 5: Global Recorded Music Industry Revenues, by Format (USD bn)



Source: IFPI, Epoch Investment Partners. Estimates from 2017 to 2021.

as increased concentration in most sectors during recent decades.

Figure 6 illustrates the price-quantity tradeoff facing a company that possesses pricing power. While rarely perfect monopolies, tech companies cannot be analyzed as price-taking firms that operate in a perfectly competitive sector. Rather, they face downward sloping demand and marginal revenue (MR) curves as depicted in the highly stylized and simplified chart on the following page. The firm maximizes

profit by setting MR equal to marginal cost (MC), which is assumed to be constant at \$40. This implies a quantity produced of 30, and a price charged of \$70 (which is read off the demand curve where Q=30). In this example, the company’s revenue is \$2,100 and consumer surplus is \$450 (= ½ * [100-70]*30), which is the area of the triangle that lies below the demand curve, but above the price line at \$70. Consumer surplus is the difference between the total amount consumers are willing and able to pay and the total amount they actually do pay.

We now extend this basic framework by examining what happens when the Digital Age allows firms to dramatically lower their marginal cost curve. Before doing this, it is important to stress that lower marginal costs do not mean zero. No company, even in the Digital Age, is able to scale its business meaningfully without incurring some additional expenses. For example, Amazon needs to build more warehouses, Netflix needs to produce more content, and even Facebook must now hire thousands of content moderators. There is no such thing as a purely digital platform with zero marginal costs, at least not yet.

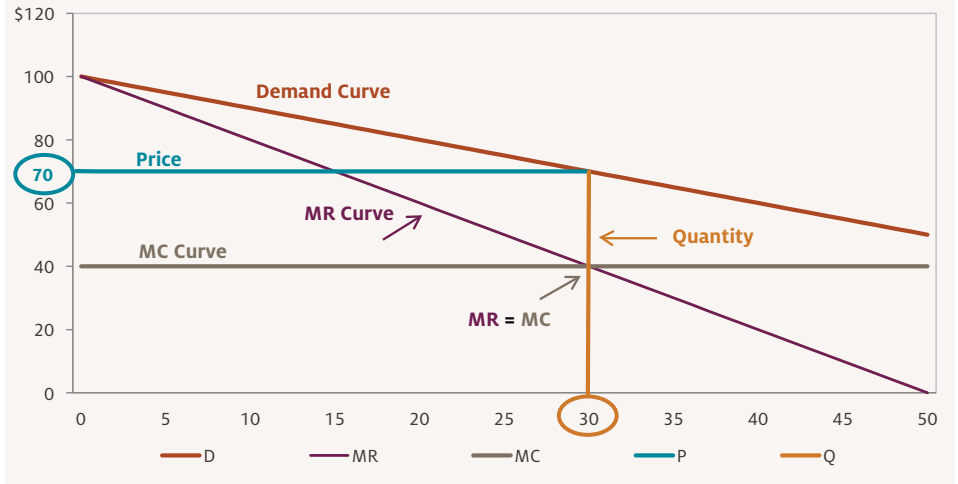
With that in mind, **Figure 7** shows what happens when the Digital Age results in marginal costs declining dramatically. In this case we assume its constant marginal cost falls from \$40 to \$10, and now intersects MR when the quantity produced is 45 (up from 30 previously). Even though the price declines from \$70 to \$55 (from the demand curve where $Q=45$), the firm’s revenue increases from \$2,100 to \$2,475 ($=45 \times 55$). Consumers are also much better off, with their surplus more than doubling to just over \$1,000 ($= \frac{1}{2} \times [100 - 55] \times 45$). Having shown that lower marginal costs create prodigious benefits for both sides of the market, we now examine a somewhat more complicated extension by introducing network effects.

“Multi-sided Platforms are the Best Business Models Ever Created”

The quote immediately above is from MIT Professor Andrei Hagiu, who attributes the success and profitability of platform companies to network effects and their being asset light. He also stresses the prevalence of platform markets in which revenues flow primarily to the top players in the space. This occurs because digital businesses are often associated with winner-takes-all dynamics, featuring intimidatingly large upfront costs, combined with significantly lower marginal costs (of production and distribution of digitized products). These supply-side economies of scale give market leaders a huge cost advantage, resulting in a small number of winners versus an ever growing list of laggards.

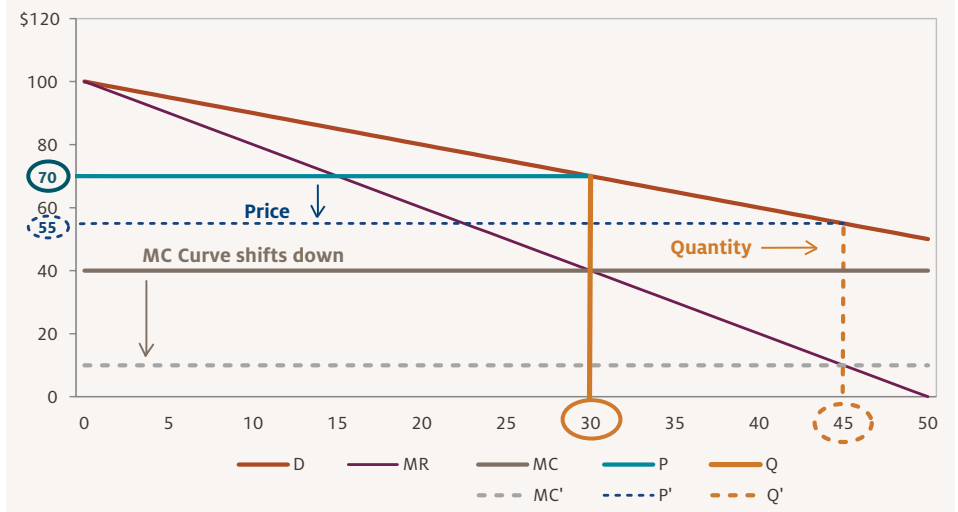
Network companies possess pricing power, which is the first step in explaining their impressive profitability.

FIGURE 6: The Profit Maximizing Problem Facing a Company that Possesses Some Pricing Power



The Digital Age results in lower marginal costs, driving increased output and a lower price for consumers.

FIGURE 7: Lower Marginal Costs Increase Both Firm Revenues and Consumer Surplus



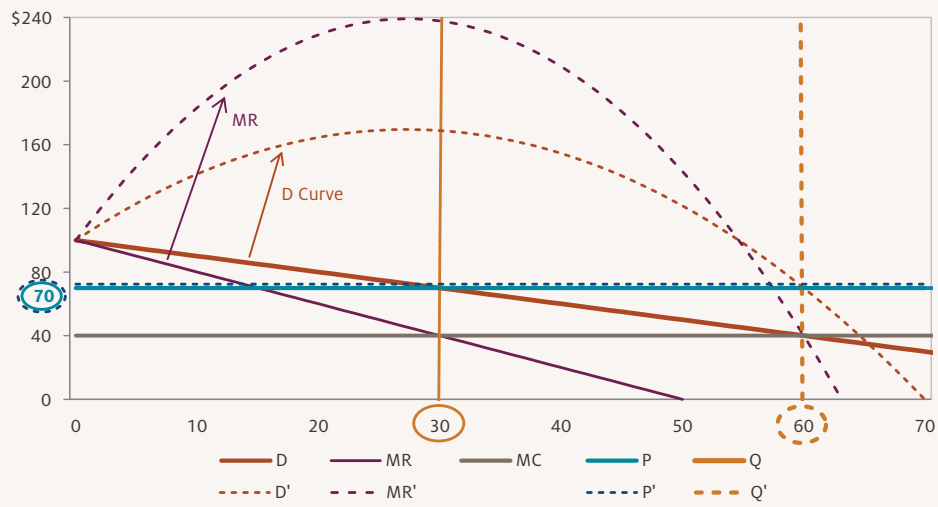
Equally important to the winner-takes-all phenomenon are demand-side economies of scale, or network effects. Fax machines are an excellent example of how network effects work, but Facebook is probably the best known and most frequently cited example today. According to Metcalfe’s Law, the value of a network is proportional to n^2 , where n is the number of active members. This exponential value payoff creates very powerful economics, especially if the cost of running the network increases linearly in n .

Additionally, indirect network effects can also be powerful. For example, an increase in the number of iPhone users encourages more app developers to invest in the platform. One impressive result is that Apple’s global developer community has earned over \$70 billion since the App Store was launched in 2008. A similar effect attracts more drivers to Uber, homes to Airbnb, sellers to Amazon, and so on.

It is important to stress that these effects hold regardless of which type of platform

Network effects are immensely beneficial for dominant firms and their consumers.

FIGURE 8: The Influence of Network Effects on Demand and Marginal Revenue Curves



is adopted. The more traditional type is transaction-based, consisting of a marketplace in which customers pay for a product or service (e.g., Amazon or Uber). A second type has been embraced by social networks, such as Facebook, that gain revenues by selling advertisements. Both types of networks possess the same underlying dynamic, which we will now illustrate.

The first thing that jumps out from a glance at **Figure 8** is that network effects transform the firm’s linear and downward sloping demand and MR curves (as in Figure 6) into hump-shaped functions. This occurs because the value of the network actually increases with output, at least initially. We revert to using the initial MC line, constant at \$40, which intersects the MR curve when the quantity produced is 60 (up from 30 in Figure 6). The price charged is unchanged at \$70 (this is just a coincidence and not a general result), so the firm’s revenue increases dramatically to \$4,200 (doubling from \$2,100). Consumers are also much better off, with their surplus increasing almost tenfold to roughly \$4,270. No wonder so many platforms have grown so remarkably quickly and have such devoted customers. While this is admittedly a specific and highly stylized example, the key economic takeaway is quite general. And we can see clearly why so many dominant platforms earn neo-monopoly profits and are inordinately valuable.

Additionally, many tech companies have invested heavily in mining customer data. By gathering and storing detailed client information, and then by analyzing it using artificial intelligence, they are able to create a much smarter platform. For example, this approach is used to generate customer recommendations by Amazon and Netflix; to sell targeted advertising by Facebook and Google; and for A/B testing by pretty much everyone (especially video games). By knowing more about its customers, platforms are able to increase sales and improve client retention. In the context of Figure 6, this flattens demand and MR curves, dramatically increasing firm revenues. It also significantly improves consumer surplus, although concerns are rising regarding data ownership and personal privacy.

A flatter, more elastic demand curve also results from bundling, that is the practice embraced by tech companies of offering complementary goods. One example is Airbnb’s expansion from accommodation into experiences and restaurants. A second is Google’s extension of its ubiquitous search brand into mail, maps, travel, translation, news, docs, YouTube, Google Play and Android, not to mention cloud computing, autonomous vehicles (Waymo) and machine learning (DeepMind). All this activity, wind-assisted by 200+ acquisitions,

has helped make Google.com the world’s most visited website and the most valuable brand (on some measures #2 behind Apple). Amazon also understands the benefits of bundling and complementary goods (e.g., Amazon video, Audible.com, Kindle, AWS, Echo, Whole Foods), as is apparently the case with most tech companies.

A final example that can be analyzed using this framework concerns the impact of improved digital infrastructure on the demand for tech products and services. In many ways this is similar to what happened a century ago, when better roads and highways resulted in greater demand for cars. Today’s tech companies benefit from broad developments such as faster processing power (as per Moore’s Law), cheaper and better data storage (e.g., remotely through cloud services), improving network bandwidth and transmission capacity (such as 5th generation mobile networks), lighter and longer-lasting batteries for devices, and advances in artificial intelligence and machine learning. Better digital infrastructure will help all tech companies and, in the context of Figure 6, we can think of this as driving an upward shift in the demand and MR curves. As in the previous examples we’ve discussed, this has the potential to dramatically increase both firm revenue and consumer surplus. Think of the impact the smart phone has had on the business models of platforms like Uber and Airbnb, or improved bandwidth has had on streaming services such as Netflix and Hulu.

IV. Macroeconomics

Tech is the New Macro: The Digital Age Entails a Radical Reevaluation of Macroeconomics

“It ain’t what you don’t know that gets you into trouble. It’s what you know for sure that just ain’t so.”

(Quote falsely attributed to Mark Twain)

Having explored what the Digital Age means for the microeconomics of businesses and their profitability, we now briefly examine its implications at the macro level. Just as network effects and the (near) zero marginal cost of platforms

entails a fundamental rethink of the microeconomics of the firm, we believe the acceleration in technology requires that we reconsider many of our preconceptions about macroeconomic relationships.

For a start, we now live in a capital-light economy as businesses replace “atoms” with “bits.” This can also be viewed as substituting traditional capex with R&D spending and software, or tangible with intangible capital. This is the theme of a terrific new book, *Capitalism Without Capital: The Rise of the Intangible Economy*, which shows that intangible or knowledge-based capital is growing rapidly and already exceeds tangible investment in economies such as the U.S. and U.K. This strongly suggests that tangible capex requirements will continue to decline in importance. For example, business investment averaged 53% of U.S. corporate profits from 1970 to 2001, but this has declined to an average of only 20% since then. We don’t believe this is a temporary phenomenon, and in coming years expect capex to constitute a much smaller share of profits than it has historically.

Second, tech is inherently deflationary, placing significant downward pressure on wages and consumer prices, and flattening the Phillip’s curve. This is not to say that the economic cycle is dead and that a sub-4% unemployment rate won’t cause some degree of wage acceleration. However, fears of much higher inflation and a doubling of long bond yields strike us as greatly misplaced. Although we expect most central banks to tighten policy over coming quarters, we believe they will be able to do so at a much slower pace than has historically been the case. Given this, we expect that nominal bond yields will rise only moderately, which should allow equity multiples to remain elevated.

Next, overall productivity growth in the economy is understated, partially because of mismeasurement of innovation in the digital economy. Also important is the large and growing gap between sectors where the output is primarily digital (tech, content, finance, and professional and technical services) and the physical industries (such as manufacturing, construction, mining, wholesale and retail trade, utilities, healthcare, hotels, restaurants

and transportation). In “The Coming Productivity Boom,” Mandel and Swanson emphasize that digital industries account for 70% of private sector investments in IT, even though they represent only 25% of employment. This contrasts sharply with the physical industries, which account for 75% of employment, but make just 30% of the investments in IT. A key consequence of this large and growing IT investment gap is shown in **Figure 9**. That is, productivity growth in the digital industries has averaged an impressive 2.7% over the last 15 years, whereas productivity in the physical industries rose by just 0.7% annually, leading to anemic growth for the overall economy.

Further, there has been a marked improvement in profitability during the Digital Age (**Figure 10**). Corporate profits, as a percent of GDP, averaged 5.8% from 1952 to 2001, but have since soared to an average of 8.7% (a remarkable 50% increase in the profit share of GDP). There are two key drivers of this improvement—lower capex requirements and a smaller share of GDP going to labor (as tech replaces workers).

Additionally, the higher profits have been concentrated among the few winners. As new technologies have strengthened network effects, there has been an associated increase in sector

concentration. In fact, more than 75% of U.S. industries have experienced an increase in concentration levels over the last two decades. Further, U.S. firms in industries with the largest increases in concentration have enjoyed higher profit margins and higher return on assets, which suggests that market power is becoming an increasingly important source of value. Consistent with a winner-takes-all economy, **Figure 11** shows that firms in the 75th and 90th percentile have enjoyed dramatic increases in their return on invested capital (ROIC) since the turn of the century. Crucially, there appears to be significant persistence to these oversized returns, suggesting wide digital moats are keeping potential competitors at bay and preventing them from bidding returns down toward their weighted average cost of capital (WACC) as textbooks state should (eventually) occur.

Finally, the accelerated pace of technology in the Digital Age means disruptive innovation is affecting every sector of the economy, and not just tech. Further, although many commentators assert that we are in the late innings of this transformation, we believe nothing could be further from the truth. As Moore’s Law and the power of exponential progress imply, change is much more likely to accelerate than to slow down.

Since 2000, digital industries have increased their productivity by about four times more than physical industries.

FIGURE 9: Productivity of Digital and Physical Industries (Index 2000 = 100)



Source: Mandel, M. and B. Swanson, “The Coming Productivity Boom,” 2017.

Implications for Investors

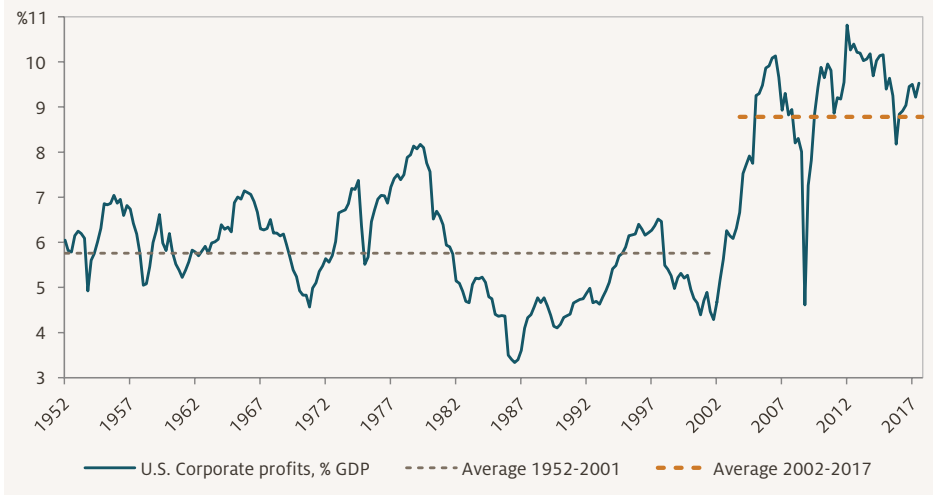
The Digital Age and the transition from “atoms” to “bits” implies a capital-light economy in which technology is being substituted for labor. This points to higher ROE—in fact, all three components should rise. Additionally, platform technologies, network economics and winner-takes-all markets favor global champions. Disruptive innovation naturally produces more laggards than winners, but that is especially true during periods of exponential progress, such as we are currently experiencing.

Understanding how companies will adapt their business models in this environment is central to assessing their ability to produce free cash flow on a sustainable basis. Capital allocation processes will also be influenced, as capital-light business models combined with higher profits as a percentage of GDP will allow many companies to increase dividends and buybacks, keeping overall payout ratios high relative to historical norms.

Epoch has always favored companies that possess superior managements with competent capital allocation policies, believing they are the most probable winners. These attributes are likely to be more important going forward, as management is tasked with creating value by marshalling talent and technologies during a period of unprecedented innovation and disruption.

Corporate profits have risen markedly during the last fifteen years.

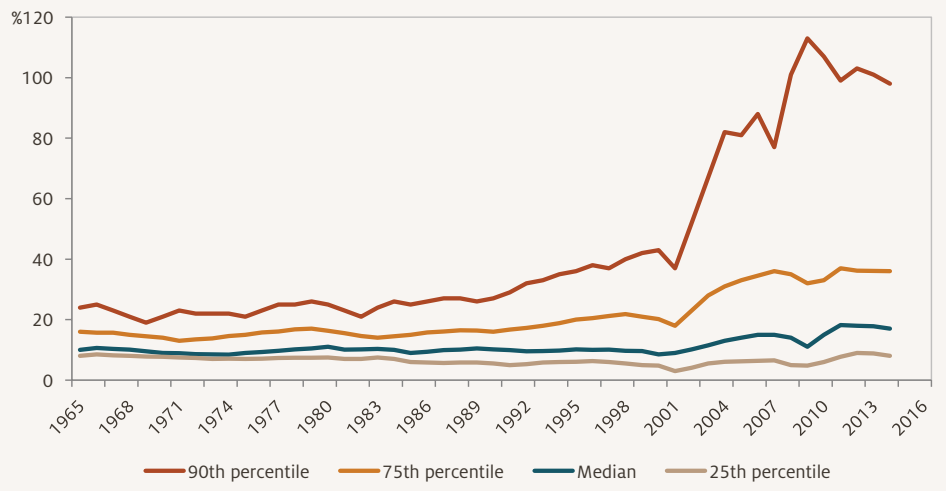
FIGURE 10: U.S. Corporate Profits (% of GDP)



Source: Epoch Investment Partners, Bloomberg

Technology has resulted in increased sector concentration, with a small number of dominant firms in the winner-takes-all economy

FIGURE 11: ROIC (% Ex-goodwill) for U.S. Publicly Traded Firms (Ex-Financials)



Source: Council of Economic Advisors, 2016.

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