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DISRUPTIVE TECHNOLOGIES AND THEIR IMPLICATIONS FOR ECONOMIC POLICY: SOME PRELIMINARY OBSERVATIONS

D. LEIPZIGER AND V. DODEV*

I. Introduction

It is generally accepted that technological innovation has been at the core of firm level productivity gains and the economic growth of countries. This general proposition as described by Solow (1956) and enhanced by Romer (1990), Aghion and Howitt (1992), and others embeds in it the notion that more productive firms will displace less productive ones in a Schumpeterian fashion. The exponential rise in economic growth since the second industrial revolution and the massive increase in living standards serve as a historical testament to the importance of technological innovation. We have seen technology's important role in the catch up of emerging market economies (EMEs) with advanced economies, notably in the case of the high-growth East Asian economies (Leipziger, 1993). This was largely done through learning and absorbing technologies from abroad, along with successful resource mobilization and the building up of human and physical capital (Yusuf, 2012).

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As a catalyst for economic growth, technological progress provides much potential upside, but it can also be a disruptive force for labor markets and established business models. Disruptive innovation, as coined by Clayton Christenson (*The Innovator's Dilemma*), refers to an innovation that creates a new market by applying a different set of values, and which ultimately (and unexpectedly) overtakes an existing market. It does this partly by harnessing new technologies, but also by developing new business models and exploiting old technologies in new ways. Products based on disruptive technologies are typically cheaper to produce, simpler, better performing, and more convenient to use

Disruptive technologies have the potential to impact growth, employment, and inequality by creating new markets and business practices, needs for new product infrastructure, and different labor skills. This, in addition to affecting existing firms in established markets, can also affect the labor market, incomes of workers, and ultimately the distribution of income. Examples of disruptive technologies include email, the personal computer and laptop, and smartphones, which have revolutionized communication and the way that we work or spend leisure time, and have displaced many products such as typewriters, mainframes, pocket cameras, and GPS devices, among others. New business models are also disrupting entire industries, such as Uber with taxi cabs, Netflix with satellite and cable television, and Skype with telecommunications.

Disruptive technologies can certainly benefit the consumer by providing cheaper, more accessible goods or services. They will have potentially negative effects on firms, however. Indeed, Christenson argues that most firms are slow to anticipate or react to disruptive forces. Firms may therefore suffer declines in shareholder value and lose markets. The knock-on effect on labor markets is more unsettling as workers are often less well placed to retrain, retool, or relocate, and traditional program of adjustment assistance have proven to be largely ineffective.

This creates an issue for public policy as governments may be confronted with the effects of disruptive technologies in the form of displaced workers and increased demands for assistance.

For these reasons, a closer look at disruptive technologies is warranted, especially during times of both rapid technological change as well as shifts in the distribution of income that may hurt the owners of labor rather than the owners of capital. In a way, this corresponds to the concerns raised by Piketty (2014) and others − that inequality is growing and that prevailing trends may yet be re-enforced by technological change, part of which can be characterized as disruptive innovation.

The McKinsey Global Institute (MGI) has identified 12 areas which exhibit the greatest economic impact and potential to cause disruption by 2025: mobile Internet, automation of knowledge work (artificial intelligence, AI), the Internet of Things, cloud technology, advanced robotics, autonomous and near autonomous vehicles, next generation genomics, energy storage, 3-D printing, advanced materials, advanced oil and gas explorations, and renewable energy (Manyika, et al., 2013) (Annex: Exhibit 1). These trends were chosen using four criteria including high rate of technological change, broad potential scope of impact, large economic value affected, and potential for disruptive economic impact. Together they are estimated to affect trillions of dollars of economic activity and tens of millions of workers. (See Annex: Exhibit 2 for a detailed example of 3D printing as a disruptive technology and its economic effects.)

These disruptive trends are ushering in a new era in which digital technologies are meeting or surpassing the capabilities of humans, even in tasks which do not follow a straightforward application of existing rules and were impossible to automate before, such as those involving communication or pattern recognition in uncertain or changing environments like the road. Moore's law is often cited as a way of understanding increases in computing capabilities, stating that processing power of computers doubles every two years. This means that there is both exponential growth in computing capability, and that computers of the same processing power get cheaper quickly. The outcome of increasingly less expensive and more powerful computers is affordable devices which are reaching human level performance.

The potential positive impact on economic activity, and hence economic growth, is clear even if magnitudes are at best guesses; however, the issue of impact on labor markets is far more serious. Labor-saving technological change is nothing new, indeed the 1960s exhibited huge alarm-bells concerning automation, which in the end were exaggerated worries. One may glibly say that it will take more than robots to build robots, but the pace of disruptive technologies that can influence manufacturing via robots and 3D printing is perhaps over-shadowed by the advances in AI that have the potential of displacing workers in the service sectors at an even more rapid pace and with more significant consequences. This reflects the fact that a) most advanced economies are now dominated by service sector employment and that b) most new job creation in the advanced economies over the last few decades has been in the service sectors of economic activity.

Disruptive technologies have different implications for firms, employment, consumers, and nations. Consumers are arguably poised to benefit the most as new technologies allow cheaper, or free, and more sophisticated goods and services to emerge. The effects on employment include some positives, such as increased efficiency and workplace flexibility, but the negatives are possibly greater in magnitude. Large scale displacement of not only manual and routine, but cognitive and non-routine, labor will hollow out both middle and low income production and service jobs, and affect high skilled knowledge work as well. Labor will also find difficulty adjusting in terms of skills as jobs are redefined and new roles are created. There will be an increased need for education and re-skilling, and the development of a comparative skills advantage to machines.

Firms in general will benefit from labor costs savings through increased labor efficiency and the transition of some tasks to computers and machines, and those which can capitalize on disruptive trends by moving into new products and markets will be the most advantaged. Much like labor, however, some firms will be displaced as products and services become obsolete, free, or unprofitable. The firms which can adjust successfully will likely be those which are well diversified and able to sustain the disruption of single industries, such as Siemens[1], or companies which invest in disruptive trends, such as IBM, which has a renewed focus on areas such as cloud computing, mobile, analytics, and AI.

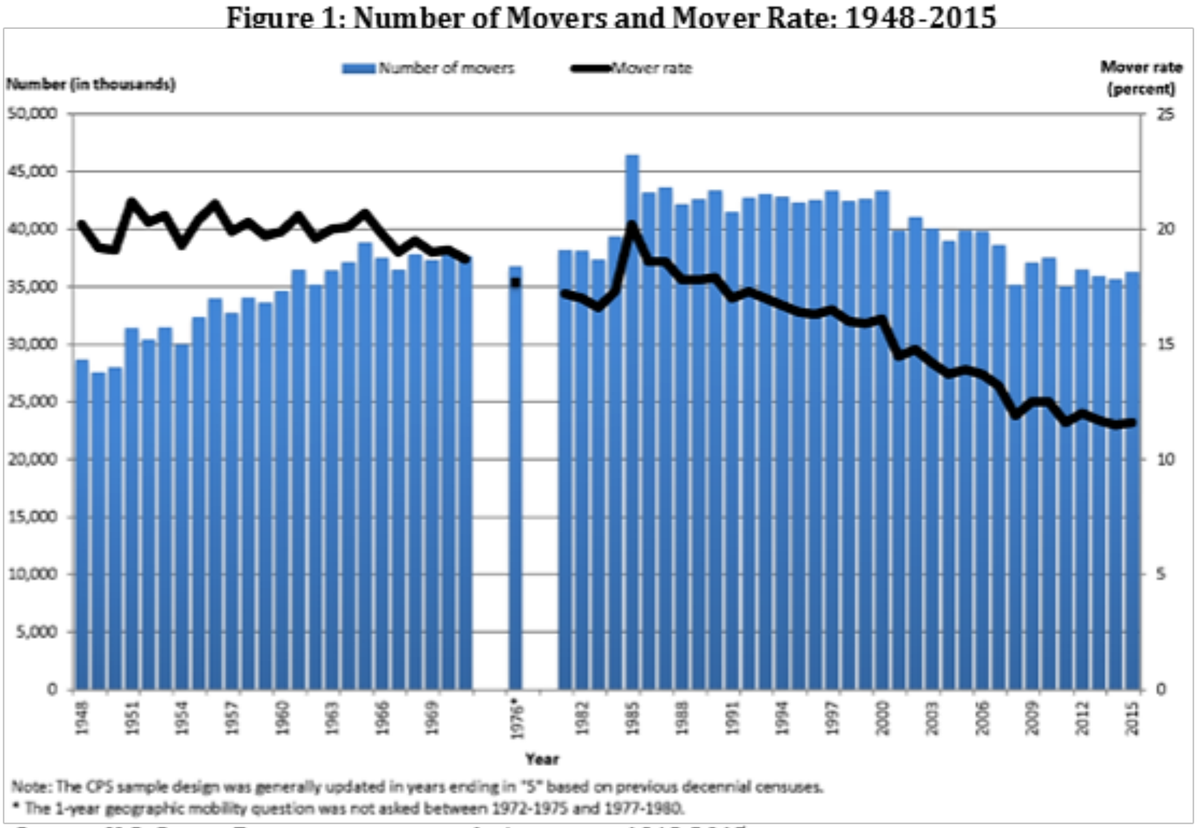
Nations which will be able to cushion themselves best from the negative consequences of disruptive trends and facilitate adjustment are those which can handle the negative effects on employment and increasing income inequality. These would include nations with high skilled and educated populations or access to high quality and affordable higher education; social programs and safety nets, such as unemployment assistance and reskilling; and those with higher degrees of labor mobility. Labor market programs are largely identified with countries, such as Sweden and Denmark, that have a proclivity for public sector interventions, the fiscal capacity to do so, and the political support for redistributive programs. This is seen most clearly in the differences between ex-ante and ex-post measures of inequality, namely, the Gini Coefficient

[1] Siemens' business areas include information and communication, automation and control, power, transportation, energy, healthcare, lighting, finance and real estate.

(one measure of inequality of income) which shows huge changes due to government tax and redistributive policies in Scandinavia in particular (OECD, 2015).

Labor market flexibility and labor's physical mobility are other factors often associated with easier adjustments to shifts in labor demand. The U.S. has historically been seen as an example of a country with flexible labor markets (viz., characterized perhaps by the phrase easy to hire and easy to fire) as compared to Western Europe especially. Moreover, labor's mobility was always seen as a plus, although as seen in Figure 1, the mover rate in the U.S. has declined significantly over the last twenty years, making adjustments in the labor market all the more difficult. Whether this is due to dual-income earners or other factors is not clear, and one cannot exclude the possibility of amenities and politics in certain parts of the country being impediments (see Moretti, 2012 and others).

Figure 1: Number of Movers and Mover Rate: 1948-2015



Source: U.S. Census Bureau, current population survey 1948-2015

II. The Growth Story

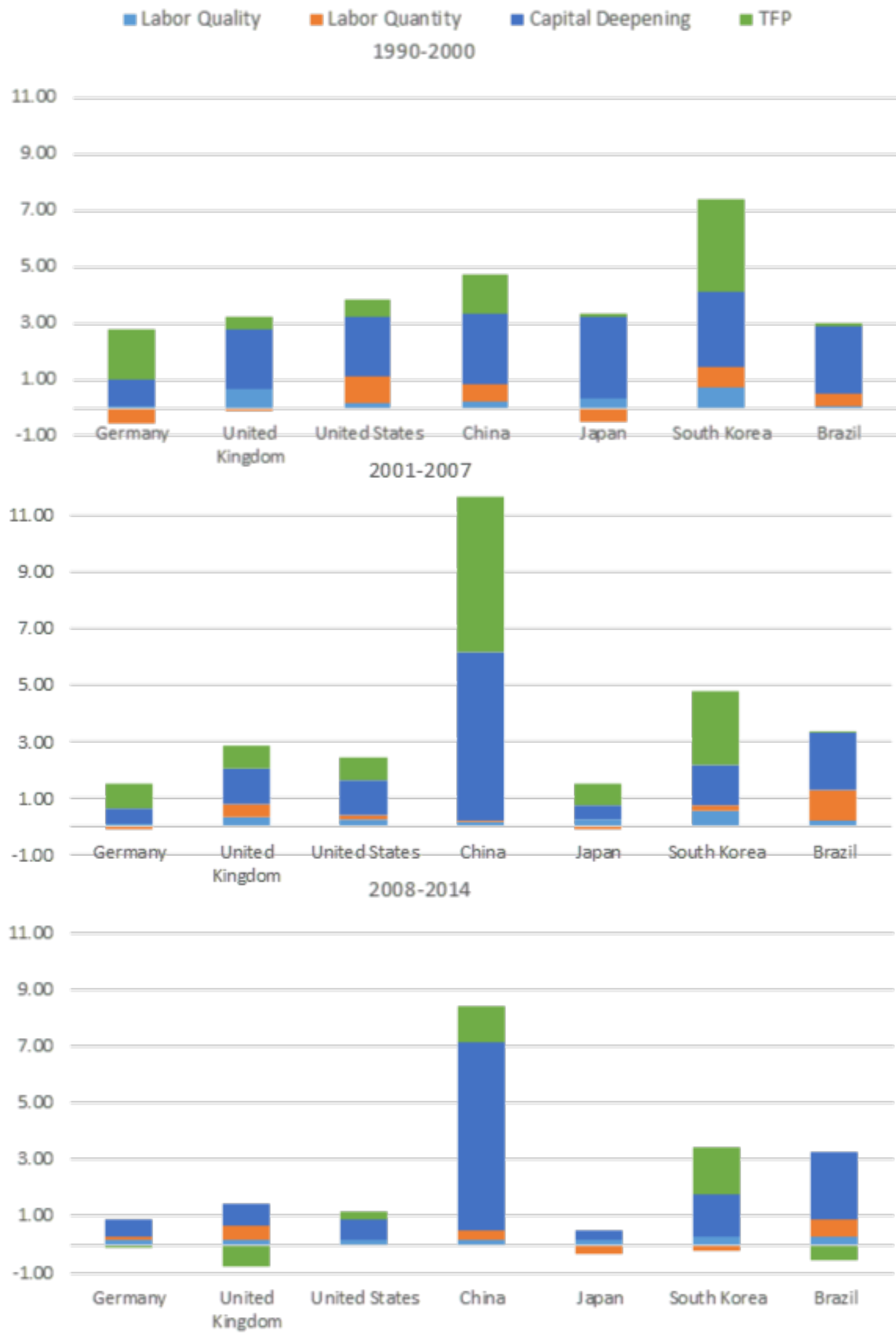
The estimated economic effect of disruptive technologies is vast, in the tens of trillions annually, and it is thought that these technologies have significant potential to drive global growth by creating new markets and products (Manyika, et al., 2013). Historically, the bulk of cross country differences in GDP per capita have been a result of cross country gaps in multi-factor productivity (MFP) and, to a lesser extent, due to human capital. Over the past decade, closure of these gaps have accounted for much of GDP growth, and MFP will continue to be a driver of convergence in the future. Capital deepening has also contributed to growth, but with decreasing returns to capital and a slowdown to capital accumulation, it is not likely to be a long term growth driver in most countries (Johansson, et al, 2012). The same applies for labor, as demographic shifts and aging populations, especially in advanced economies, have adverse growth implications.

A number of OECD countries have been experiencing a slowdown in labor productivity since 2000, and in fact, data shows a broad-based decline in the contribution of labor (human capital accumulation) to GDP growth across countries, a pattern which will continue into the future (OECD, 2015a) (Figure 2). There has also been a slowdown or flat-lining in the contribution of capital deepening after 2000 in most OECD countries, a trend exacerbated after 2007, along with declines in multi factor productivity, the contribution of which is now negative in many countries. It is important to note, however, that MFP is partially a result of investment in intangible, knowledge-based capital (KBC)[2] and technology, which may not suffer from the same decreasing returns to scale and can be a source of sustained long term growth. This

[2] This includes R&D, firm specific skills, organizational know-how, databases, design and various forms of intellectual property.

suggests that the slowdown in MFP may partly reflect the pull-back in the pace of KBC accumulation in the early 2000s, showing that the diffusion of knowledge and technology, as captured in KBC accumulation, has a measured impact on global growth (OECD 2015a).

Figure 2: Drivers of GDP Growth Since 1990
Contributions of Production Factors to GDP Growth

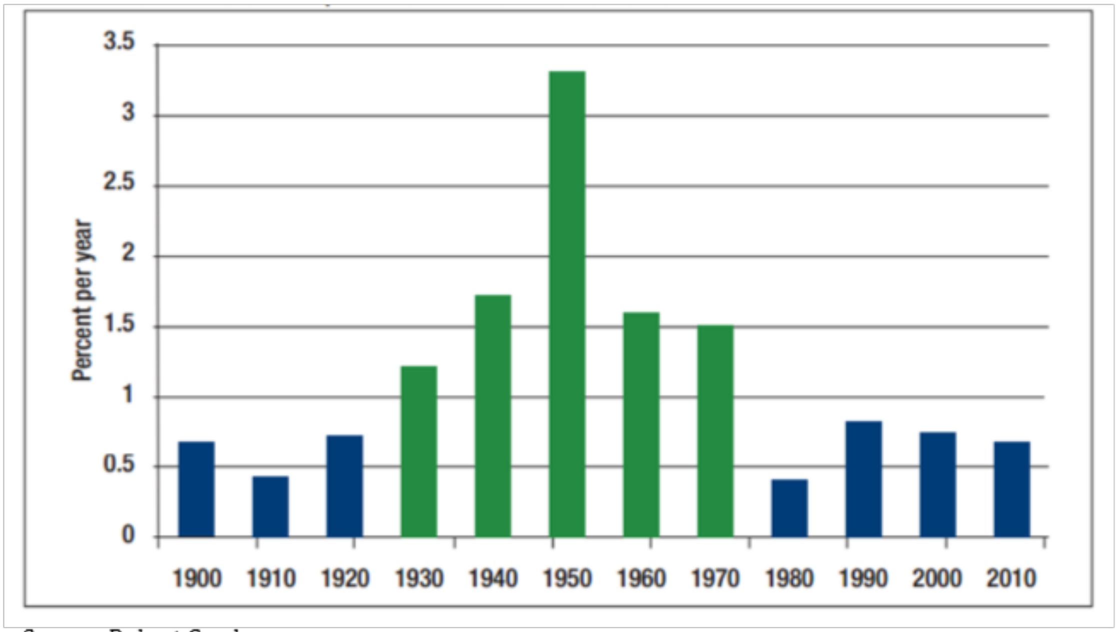


Source: Author calculations based on Conference Board Total Economy Database

The effect on economic growth of disruptive technologies cannot be fully accounted for in GDP figures, as much of the benefit is not captured in the market value of associated goods and services. This includes the benefit of free products and information (Google, Skype, WhatsApp, Wikipedia) which replace paid products, entertainment value from social and digital media, increased buying choices through online platforms, and reduced search and transaction costs, among others (Brynjolfsson and McAfee, 2014).

Some are not as optimistic. Robert Gordon, for example, argues that technology will not improve economic performance in the long run, using the United States as an example, because of four headwinds: demographics, education, inequality, and government debt (2014). These headwinds will reduce the GDP per capita growth rate from an average of 2% per year between 1891-2007, to 0.9% for the period 2007 to 2032 as shown in Figure 3. Gordon contends that these headwinds have decreased potential long run GDP, not just actual short run GDP, and that the low growth of recent years will be sustained. He shows that the annual growth rate of TFP peaked in the 1950s, and has been much lower than the mid-20th century since the 90s; thus, arguing technological progress likely will not overtake the headwinds and have a major positive impact on growth.

Figure 3: Annual Growth Rate of TFP for Ten Years
Preceding Years Shown, Years Ending in 1990 to 2012



Source: Robert Gordon

There is little doubt that we need increasingly to be wary of the measurement errors of both productivity and GDP itself in a digital world in which many sources of information and many means of communication entail almost zero-cost. Past attempts to deal with GDP inaccuracies (such as the Stiglitz-Sen Commission Report, 2009) noted failings, but we have yet to see much progress in altered measured of economic activity. On the side of technology, Aghion and co-authors (2016a) claim that we may be missing as much as 0.5 to 0.8 percent in GDP growth from a mis-measurement of new technologies by way of improved but unmeasured quality gains. This fact, notwithstanding what governments will face increasingly, is changes in employment, that may rightly or wrongly be attributed to globalization, trade, and off-shoring; or to new technologies and skills mis-matches; or to other factors (see Autor, 2013a, 2013b, 2013c, 2015 for the case of the U.S. for some empirics). One thing is clear, and that is that it would be a public policy mistake not to think ahead in terms of employment implications, even though the landscape is uncertain.

III. Effects on Employment

Disappearing Jobs: A U.S. Case

In recent years there has been much debate about jobless growth, and some have pointed to a decoupling effect as a consequence of advances in technology. As digital technologies expand and are able to handle a greater scope of routine work, machines are able to substitute less skilled and educated workers, putting downward pressure on the median wage (Brynjolfsson and McAfee, 2014). The phenomenon spreads as computers proliferate and get cheaper and employers prefer hiring more capital to labor, affecting job volumes. As new advances in artificial intelligence allow computers to expand into work that is not just routine, such as some high skilled service sector jobs, this affect will only accelerated. As such, persistent unemployment in the modern world can become a structural issue, not just cyclical.

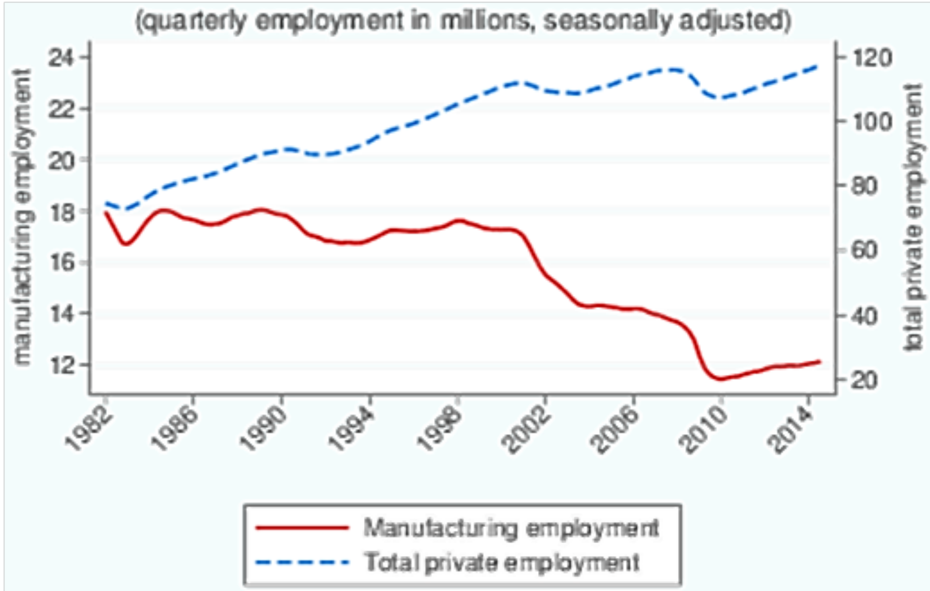
We choose to look at the U.S. as a case study because of its high degree of technological innovation and business opportunity. It is a global leader in new technology as measured by the number of patents, startups focused on disruptive trends, and gazelle firms, and it is home to notable companies such as Apple, Google, Microsoft, Facebook, IBM, and Cisco. In the World Economic Forum's 2015 Global Competiveness Index, the U.S. is ranked 3rd out of 140 countries, with notable leads in labor market efficiency (4th), business sophistication (4th), innovation (4th), and market size (2nd), and it is ranked 17th in technological readiness. The U.S. is also ranked 6th overall out of 50 countries in Bloomberg's 2015 Innovation Index, which factors in R&D (11th), Manufacturing (10th), Hi-Tech Companies (1st), Education (33rd), Research Personnel (19th), and Patents (4th).

Technological business development is also supported by low barriers to entry and availability of credit. The U.S. is ranked second among OECD nations in openness of product market regulation, which includes state ownership, barriers to entrepreneurship, and barriers to trade and investment[3]. It is also ranked 7th out of 189 economies in the 2016 Ease of Doing Business Index, with a notable lead access to credit at 2nd. Businesses are able to take advantage of a high depth of angel finance and venture capital, as the U.S. has the most venture capital investments of any economy, absolutely and as a percentage of GDP (OECD, 2015b).

The U.S. is also a good laboratory for evaluating the positive and negative effects of disruptive technology when we take into account employment trends in manufacturing and the distribution of jobs which has occurred as a result of innovation. Manufacturing employment has dropped from around 18 million in 1980 to around 12 million in 2014, as total private employment has expanded by about 50 million jobs in that period (Figure 4). Of the 27.3 million jobs which were added between 1990 and 2008, 97.7% stemmed from the non-tradable services sector, notably in government and health care (Spence and Hlatshwayo, 2012). Tradable services also experienced job growth in high end services such as management and consulting, computer system design, finance, and insurance, which were roughly matched by declines in most manufacturing areas.

[3] OECD 2008 Product Market Regulation Indicators. The indicators were revised in 2013 but data on the United States was not included. Breaking down the three categories, the U.S. ranks 2nd in state control, 2nd in barriers to entrepreneurship, and 21st in barriers to trade and investment.

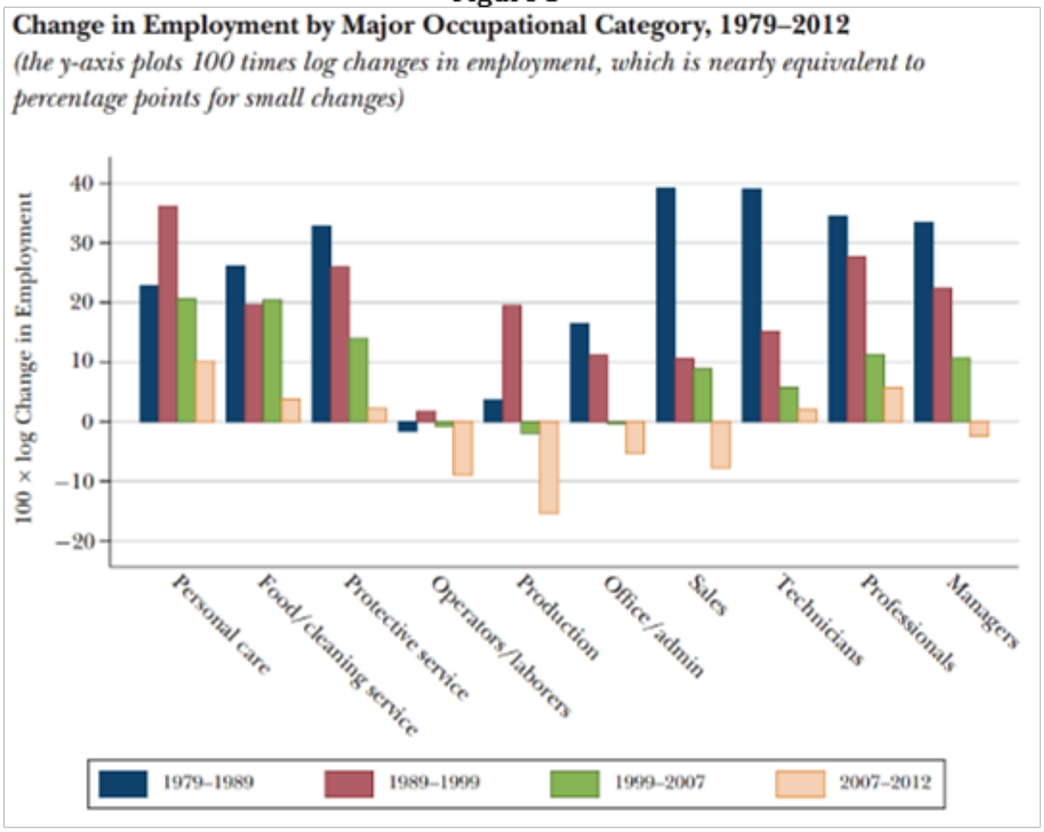
Figure 4: U.S. Employment, 1980-2014



Source: U.S. Bureau of Labor Statistics

While some of this erosion of manufacturing jobs is due to a shortage in the supply of skilled labor, offshoring and globalization of production chains, trade penetration, and some shifts in tax policy, technology is also a contributing factor (Autor, 2015). Traditionally, manufacturing and routine jobs have been the most susceptible to technological advancement. The U.S. has exhibited increasing labor market polarization with a structural shift towards low income service and manual work, as middle income manufacturing jobs get hollowed out, and towards high income cognitive jobs, where skilled labor has a comparative advantage over computers in terms of problem solving abilities. In 1979, the four "middle skilled" job categories (sales; office and administrative workers; production workers; and operatives) accounted for 60 percent of employment. In 2007, this number was 49 percent, and in 2012, it was 46 percent (Autor, 2015)(Figure 5). It is reasonable therefore to expect computerization to continue to impact service and non-routine work.

Figure 5

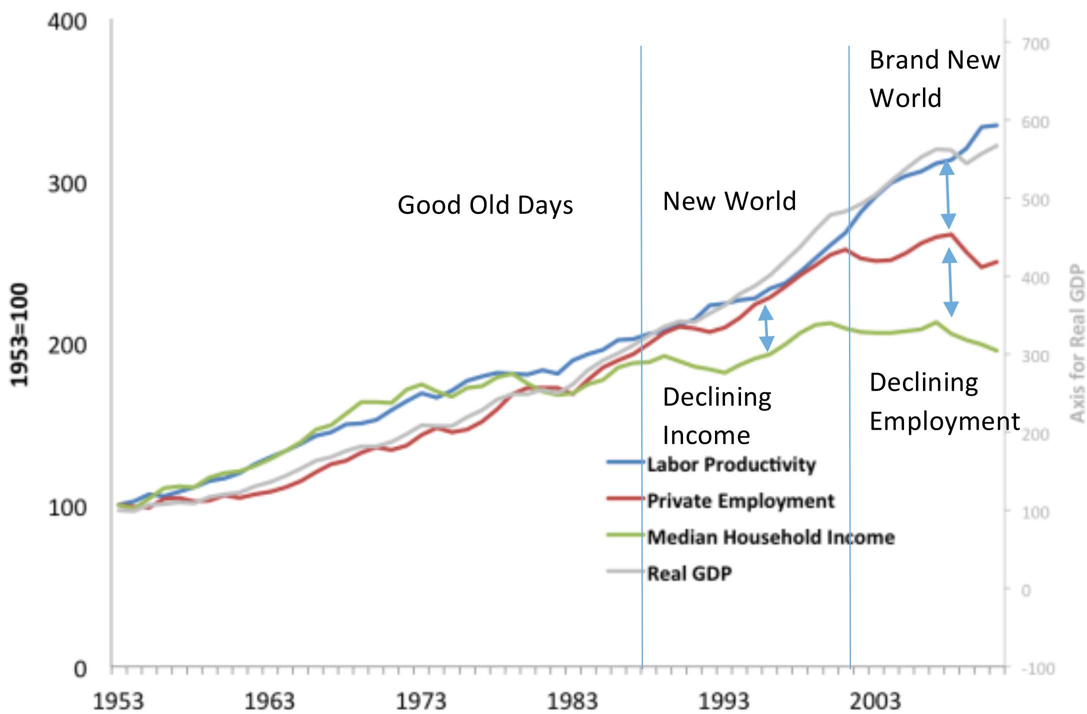


Source: Autor

A major structural phenomenon, seen in Figure 6, is that jobs and wages have become decoupled from productivity and GDP growth. The post-war trend, the " good old days", where jobs, productivity, and incomes grew in unison, stopped in the late 1980s. Employment and income have been growing at a much slower rate than either productivity or GDP since, and have even fallen some in the last decade. The effects have been seen in two main waves; in the first, spanning from the early 1990s to the early 2000s, in " the new world," the effect was mainly seen in declining incomes. Since the early 2000s, as computers and digital technologies became ubiquitous in the workplace, employment has also completely decoupled from output and productivity. This stark trend is shown as the " brand new world " in Fig. 6. This decrease in employment and the resulting decline in median income has also had the effect of increasing income inequality (Stiglitz 2012). This trend will be exacerbated with the hollowing out of middle income jobs in the age of new disruptive technologies. In the future, more wealth will go to those who make or control technology; either those already owning capital or new entrepreneurs[4].

Figure 6

US Productivity, GDP, Employment, and Income: 1953-2011



Source: Census Bureau, Bureau of Labor Statistics, Brynolfsson and McAfee

The Future Outlook in the U.S.

Looking forward, Frey and Osborne evaluate the effects of new technologies on employment by estimating the probability of computerization for 702 occupations and find that 47 percent of total U.S. employment is at high risk in a decade or two, where risk is defined as a probability of computerization of 70% or above (2013). While most automatable tasks in the past were routine, AI, through algorithms, will have a widespread effect on computerization of non-

[4] One phenomenon associated with disruptive technology is the "winner takes all" aspect in which market dominance and rents are captured by selected new entrants (Brynolfsson and McAfee, 2014)

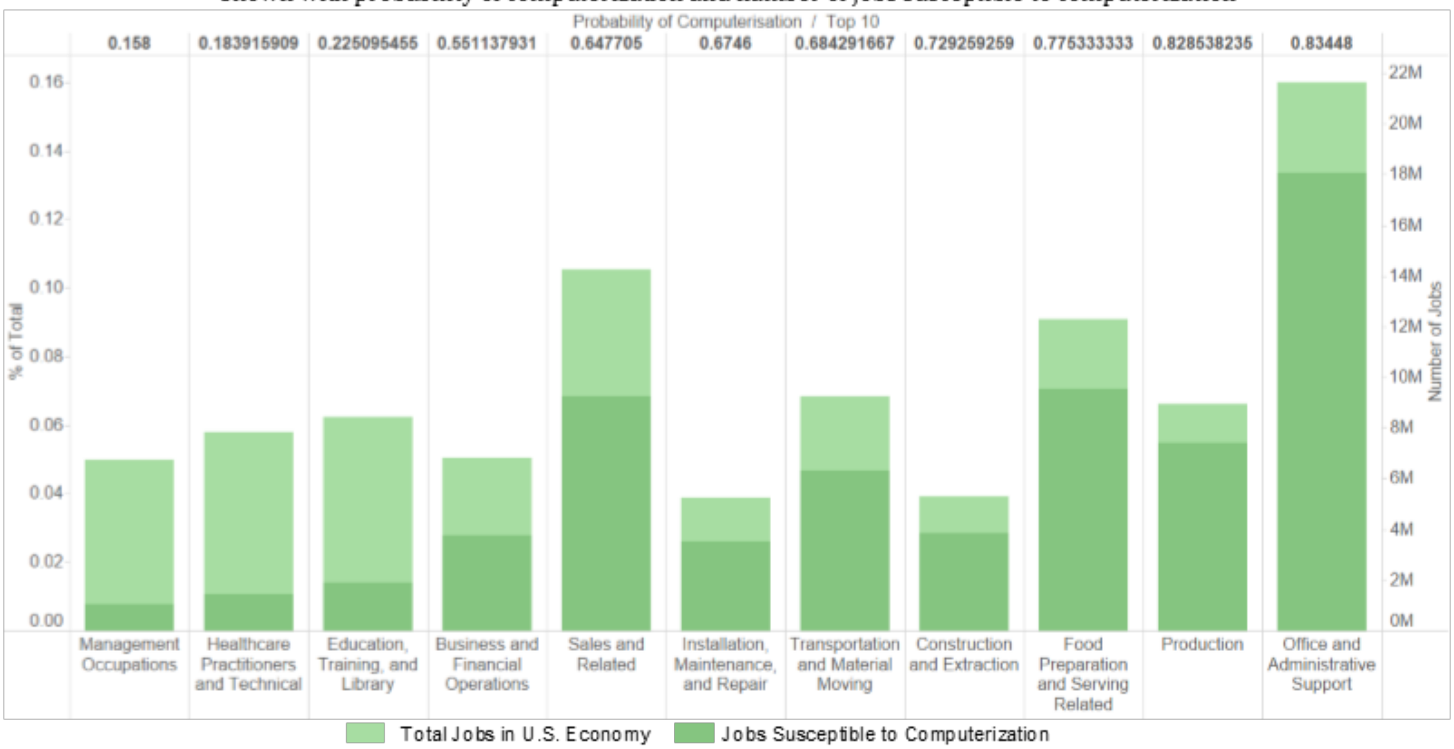
routine, cognitive tasks, such as fraud detection or healthcare diagnostics, or work in legal and financial services. MGI suggests that AI can be responsible for the replacement of 140 million knowledge workers globally by 2025 (Manyika, et al., 2013). In the near to medium term, certain activities and not whole occupations are at risk for automation. According to MGI, as many as 45% of the activities individuals are paid to perform can be automated by adapting currently demonstrated technologies, representing about $2 trillion in wages within the United States, which compares to about $7 trillion of total wages in 2014. When AI reaches human level processing capabilities, an additional 13% of work activities in the U.S. economy could be automated (Chui, 2015). Thus, even some of the highest paid jobs such as executives, financial managers, and physicians have many tasks which are susceptible to automation.

In terms of non-routine manual tasks, more advanced robotics, such as those that can climb wind turbines or perform surgical procedures, are a direct threat to jobs as robots develop greater flexibility and range of motion (Frey and Osborne, 2013). With improved sensors, robots are becoming increasingly capable of producing goods of higher quality and with greater reliability than humans, and will become a more attractive substitutes as costs decrease over time. Big data, sophisticated sensors, and the Internet of Things also merge with AI to affect the logistics and transportation industry through autonomous vehicles.

Looking at the top 10 industries in the United States, as measured by their share of total employment, which account for about 74% of jobs in 2014, some of the top employment industries are also the most susceptible to computerization (Figure 7). These include office and administrative support, production, food preparation/service, construction/extraction, sales and transportation/moving, among others. Three industries which have notably low probabilities: education/training/library, healthcare practitioners/technical healthcare roles, and management.

These industries require a high degree of originality, persuasion, and social perceptiveness and/or manual dexterity, specifically in healthcare. It is important to note that these industries also tend to have higher median wages than the others, further evidencing the thesis that low and middle income jobs will be eroded.

Figure 7: Top 10 Industries in U.S. as Measured by Total Employment
Shown with probability of computerization and number of jobs susceptible to computerization



Source: Author's calculations based on expected values of computerization from Frey and Osborne and data from U.S. Bureau of Labor Statistics

Global Trends

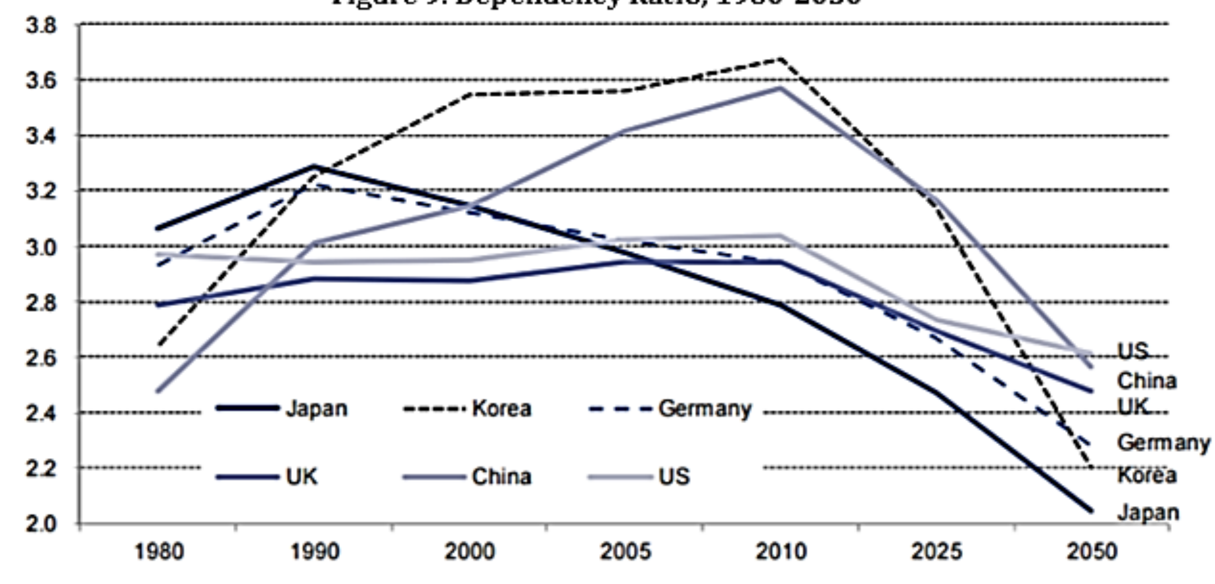
Global trends are difficult to predict and therefore estimates are equally difficult to assess without a degree of skepticism. That said, the World Economic Forum (WEF) recently estimated that there will be a net employment impact of more than 5.1 million jobs lost to disruptive labor market changes over the period 2015–2020, with a total loss of 7.1 million jobs and a total gain of 2 million jobs worldwide (WEF 2016). These estimates are based on a survey of the largest employers representing more than 13 million employees across 9 broad industry sectors in 15 major developed and emerging economies and regional economic areas. The largest impact was reported as losses in office and administrative, and manufacturing and production, accompanied by some gains in several smaller job families such as management, computer and mathematical, and business and financial operations (Figure 8). Thus growth in employment is, according to the WEF, expected to be generated from smaller, generally high-skilled job families that will likely be dwarfed by job losses; moreover, the newly created jobs will require significantly different skills which put a challenge on existing education systems (see Trajtenberg, 2016).

Figure 8: Net Employment Outlook by Job Family, 2015-2020

Source: WEF

These trends will be exacerbated by the increase in global unemployment due to global population growth and slow job creation over the period 2015-2019. In many advanced economies of Europe, North America, and Japan, demographic trends such as aging populations will lead to continued labor force declines, especially as individuals retire, creating challenges for pensions and health care. The dependency ratio, defined here as the working population divided by the young and the elderly, has been falling in major economies since 2010 or before, and is expected to continue this trend with a more precipitous decline (Figure 9). This can create a window of opportunity in many emerging markets which have more favorable demographic trends to sustain labor force growth, and will likely lead to a need for increased global mobility and migration to fill gaps in advanced economies.

Figure 9: Dependency Ratio, 1980-2050



Source: UN (2007) World Population Prospects.

Skillset Disruption and Employment of the Future

Technological trends produce an impending threat of skillset disruption by redefining, eliminating, or creating positions that require new skills and content knowledge, and an ability to interact with technology. It is estimated that nearly 50% of subject knowledge acquired during the first year of a four-year technical degree outdated by the time students graduate (WEF, 2016). This means that constant re-education and re-skilling will be needed in order to keep up with labor demand conditions. The new labor force will have to go beyond basic computer literacy and acquire skills in coding, software development, and computer science. There will be an increase in the need for developers and programmers who can create software to go with advanced machines, including robotics, or algorithms for AI. Given the exponential rate of increase in the amount of digital information available, an ability to work with data and make data-based decisions will become an increasingly vital skill across many job families. Content skills (which include information and communication technology literacy and active learning), cognitive abilities (such as creativity and mathematical reasoning) and process skills (such as active listening and critical thinking) will be a growing part of the core skills requirements for many industries (WEF, 2016). New technologies are also enabling workplace innovations such as remote working, co-working spaces and teleconferencing, which will decrease the need for fixed full time employees. Projections predict that 45 percent of workers will be freelancers, temps, and independent contractors by 2020 (Chui, 2015).

IV. Inequality

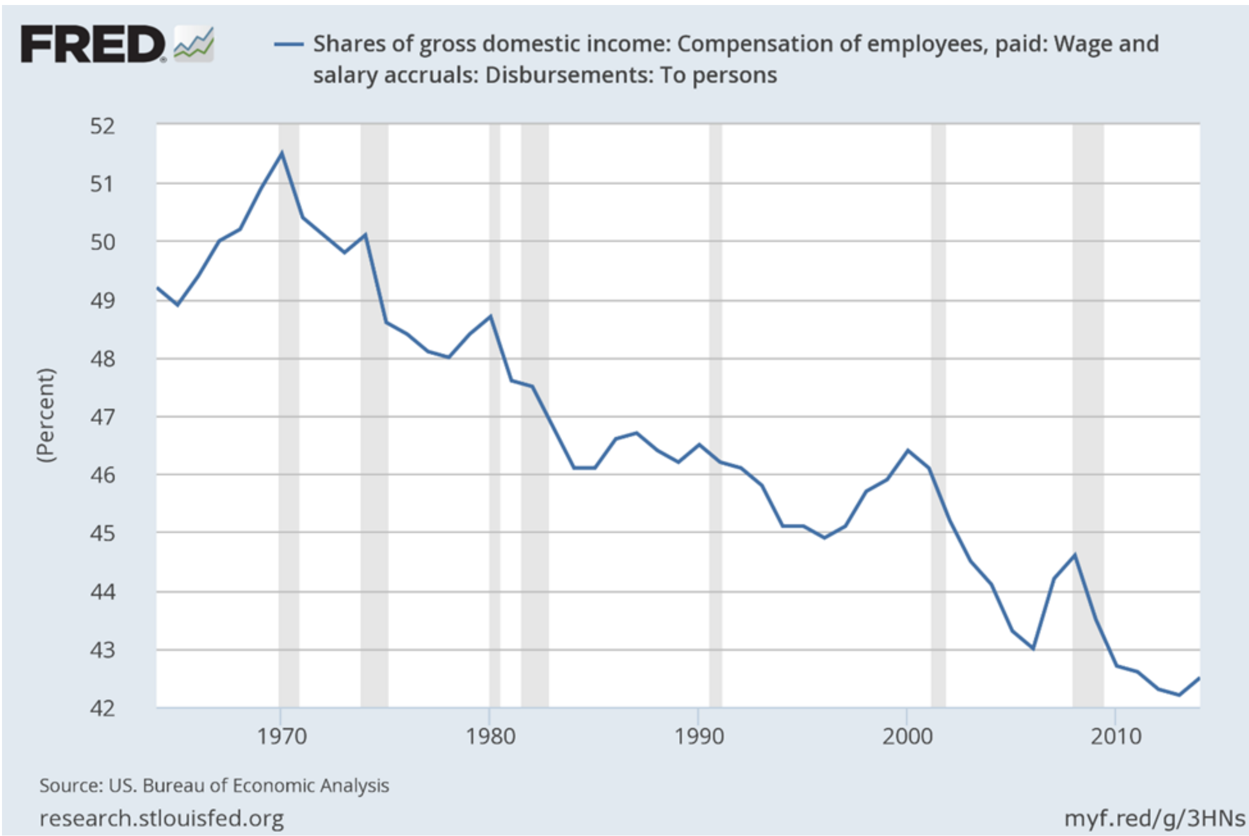
Conceptually, if disruptive technologies displace labor and median incomes continue to decouple from output, the associated economic growth and distribution of income become more unequal. Some such as Aghion (2016) have made the analogy to the lines forming for airplane flights that are bifurcated into economy and other classes of travel. With lower demand for low skilled and low to median wage labor due to work becoming increasingly automated, the owners of capital and unique skills are accruing a larger share of benefits. Should this process proceed without any offsets, such as transfer payments to compensate the income losers, one can imagine opportunities for others in related sectors to maintain their incomes also declining as innovation proceeds to lower consumption demand for a large part of the labor force. As such inequality increases as a result of two forces: 1) the growing gap between labor income and capital income, and 2) the growing gap between high earners and low earners. To be clear, however, this is not a prediction, but rather an explanation of how the impacts of disruptive technologies may be felt.

To put this hypothetical scenario into context, however, it is worth noting that the rising gap between labor and capital. The share of domestic income that goes to labor (wages, salaries, work related compensation) has been declining since the early 1970s in the U.S., as the share that goes to capital (interest, dividends, realized investment returns such as capital gains) has been increasing[5]. This trend, seen in the steadily declining share of GNI destined for labor since a peak in 1970, explains widening inequality in the U.S. in recent decades as owners of capital

[5] Some economists disagree with the extent of this trend, noting that GDP includes many things besides wages, such as proprietors' income, rental income, interest, indirect taxes and depreciation. Depreciation is especially important because owners of capital must replace or reinvest in assets that wear out or become obsolete, and computers and software, a growing share of business capital, depreciate much faster than plant and equipment, raising depreciation charges. For example, Benjamin Bridgman, shows that once depreciation and production taxes are netted out of GDP, labor's share of net income is significantly higher than its gross share.

gain a greater share of income than the general labor force (Figure 10). According to Thomas Piketty, this is what has historically taken place, with the post WWII period an anomaly (Piketty, 2014). These trends have prompted some top search for new models of growth and distribution (see Kanbur and Stiglitz, 2015).

Figure 10: Labor's Share of Gross Domestic Income



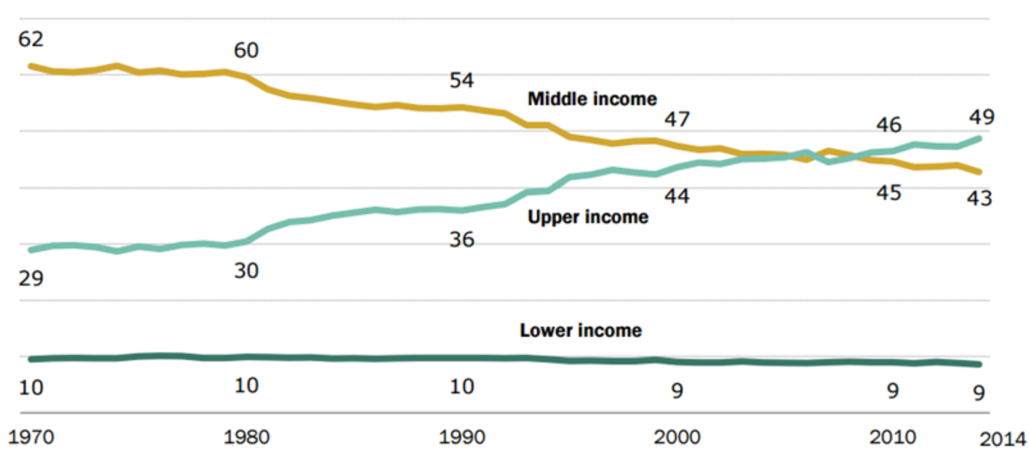
If we disaggregate real earnings and look at just manufacturing, we can see that the manufacturing driven economy peaked in 1978, at which point real wages decreased or stayed flat. This marked the transition from manufacturing to the information age as technology, such as the personal computer, started becoming more prevalent and ubiquitous in business.

The Pew Research Center's study on income inequality and the middle class in the U.S., finds that the middle class is no longer the nation's majority (Pew Research Center, 2015). The overall share of aggregate income held by middle income households[6] has decreased from 62% in 1970 to 43% in 2014, while for upper income households it has increased from 29% to 49% and for lower income households it has decreased from 10% to 9% within that period. Pew also estimates that by 2015, 29% of households fell into the lower income category, up from 25% in 1971, 21% of households fell into the upper income category, up from 14% in 1971, and 50% of households fell into the middle income category, down from 61% in 1971. At the same time, median incomes for the upper tier increased by 47% since 1970, but only by 34% and 28% for the middle and lower tiers, respectively. (Figure 11; Figure 12).

Figure 11

The share of aggregate income held by middle-income households plunged from 1970 to 2014 and is now less than the share held by upper-income households

% of U.S. aggregate household income held by lower-, middle- and upper-income households



Note: Households are assigned to income tiers based on their size-adjusted income in the calendar year prior to the survey year. Their unadjusted incomes are then totaled to compute the share of an income tier in the U.S. aggregate household income. Shares may not add to 100% due to rounding

Source: Pew Research Center analysis of the Current Population Survey, Annual Social and Economic Supplements, 1971 to 2015

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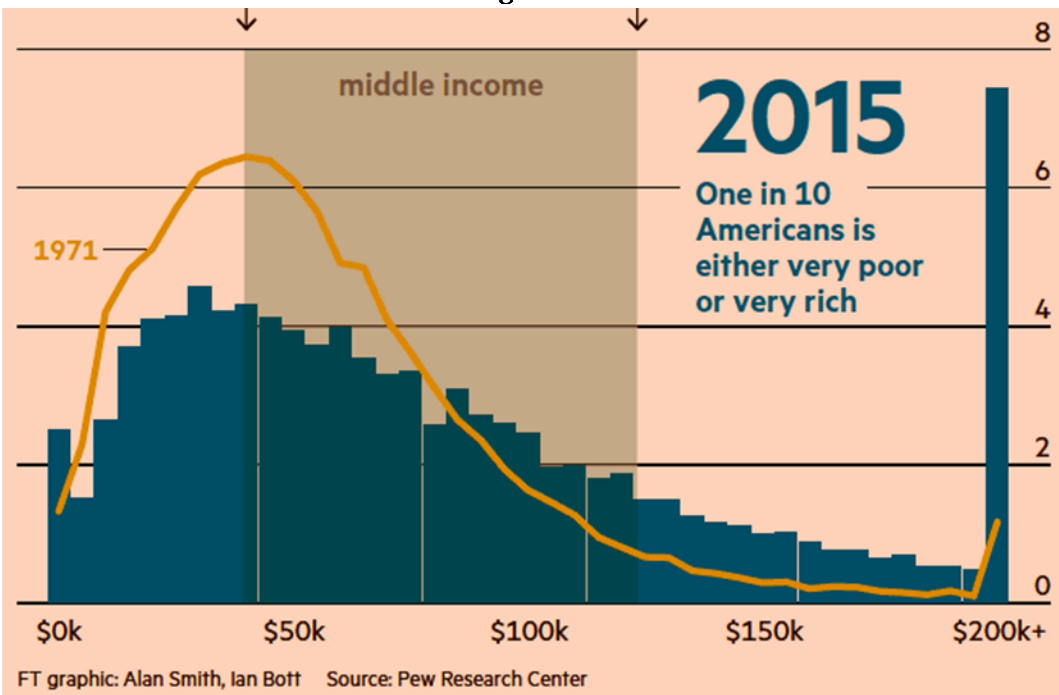
[6] Pew defines middle income as $42,000 to $126,000 for a three-person household, with upper income being $126,000 or above and lower income being $42,000 or below.

Figure 12



If this trend is being replicated in other countries other than the U.S., as argued by Bourguignon (2015), Milanovic (2016), and others, then we are witnessing a combination of increasing convergence between countries (of course led by China) at the same time that intra-country income disparities are increasing, namely greater internal divergence. This trend is associated with economic, political, and social consequences that require further study and policy debate (see, for example, the WEF's Inequality Project, 2015 as well as Atkinson, 2015); however, many technology pundits, such as Brynolfsson and McAfee argue that that further advances in technology will benefit the few and make many workers redundant.

V. Some Final Policy Observations

Public policy will need to be agile to help anticipate and manage labor dislocations. In most countries, advanced as well as emerging and developing, fiscal expenditures are largely captured by existing programs and prevailing political interests. This leaves little room for flexible spending. Moreover, governments seem singularly unconcerned and unprepared for the impact of major technological shifts that may very well cause tectonic income changes. Discussions of the new industrial age dominated by digitalization, robotics, and AI are often divorced from discussions about education and skills, for example. This needs to change.

Brynolfsson and McAfee (2014) argue that the individual, the average worker will have to build up the skills that will give them a comparative advantage over computers, including ideation and creativity, large scale pattern recognition, and complex forms of communication. Improving education can boost economic activity by providing more of the complementary skills the economy needs to take advantage of new technologies. These admonitions follow in the wake of the alarm bells run by Goldin and Katz (2009) years ago.

Nevertheless, there is still room for debate on the appropriate training needed to compete in the new digital age. The WEF, for example, also argues for a reinventing of the corporate HR function. In its 2016 Report (*The Future of Jobs*), it notes that as the rate of skills change accelerates across both old and new roles in all industries, proactive and innovative skill-building and talent management is an urgent issue, along with HR which can spot talent and skills gaps. In the longer term, they argue for rethinking education systems, incentivizing life-long learning, and re-enforcing collaboration between the public and private sectors.

As behaviorists will note, it is largely up to individuals to alter their approach to education and work. Of course, this can be aided by access to better and more accurate information, even if this simply entails a recognition that there is less certainly in the labor force, and that skill fungibility is at a premium. That said, it is often the public sector that has a complementary role to play in sheltering individuals from sudden shifts in economic fortune that are outside their ken, and also in leveling the playing field for future workers by working to create an environment of better skill acquisition. If indeed technologies going forward will be more disruptive to economic livelihoods, this will inevitably place governments in the forefront of policy solutions. Unfortunately, it appears to many that governments are currently ill-equipped for this challenge

Annex

Exhibit 1: Top 6 Disruptors

Disruptor		Effect
Mobile Internet	Increasingly inexpensive and capable mobile computing devices and Internet connectivity	Enabling more efficient delivery of services and opportunities to increase workforce productivity
Automation of Knowledge Work	Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments.	A threat to the service sector, especially with voice recognition allowing computers to interact with customers. It will allow for automation of a lot of knowledge work and make it cheaper and more accessible.
Internet of Things	Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization	A positive for industry because it allows companies to manage assets and optimize performance of production process by having improved sensors and remote monitoring
Cloud Computing	Use of computer hardware and software resources delivered over a network or the Internet, often as a service	Negates the need for having lots of hardware equipment because software and hardware is now accessible remotely over the Internet.
Advance Robotics	Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans	An obvious threat to manufacturing jobs, but can boost production and reduce costs. Also a threat to industries such as healthcare as some tasks would be able to be performed by robots, and services such as cleaning and maintenance.
Autonomous and Near Autonomous Vehicles	Vehicles that can navigate and operate with reduced or no human intervention. If regulation allows, as early as 2020 autonomous cars, aircraft, and boats can revolutionize transportation.	

Source: McKinsey Global Institute

Exhibit 2

FOCUS: 3D PRINTING

Additive manufacturing, or 3D printing, is transforming the manufacturing industry and how goods are produced, distributed, and sold to customers. It is a process of making three dimensional objects from a digital model. Unlike traditional manufacturing models like drilling, milling, and assembling parts, 3D printing builds objects by laying down successive layers of a material, such as plastics and metals, without the need for a mold or cast. The process is more efficient, cheaper, and creates less waste material than traditional manufacturing.

3D printers are now available not only as prototype and production machines, which can cost from tens to hundreds of thousands of dollars, but desktop machines, which can be obtained for as little as a few hundred dollars, making the technology available to consumers who can make small items themselves such as tools, jewelry, household objects, and art. The implications of the technology for the manufacturing industry is also vast, as 3D printing can make supply chains more efficient by allowing more on demand production, reducing the need of maintaining spare parts and large inventories, allows for greater customization of products, and allow for localized production of goods closer to consumers, reducing transportation costs.

The ability to manufacture complex and highly customized shapes and objects can impact every industry from automotive, with the production of engine parts, to healthcare, with the production of customized prosthetics or joints. Consumers will also be able to save money by creating items themselves at home. While the exact estimated effects of this disruptive technology are difficult to quantify, McKinsey global institute predicts that $11+ trillion of global manufacturing GDP will be impacted by 2025 (Manyika, et al. 2013).

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