

Annunziata, Marco; Bourgeois, Hendrik

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The future of work: How G20 countries can leverage digital-industrial innovations into stronger high-quality jobs growth

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The future of work: how G20 countries can leverage digital-industrial innovations into stronger high-quality jobs growth

Marco Annunziata and Hendrik Bourgeois

Abstract

A new wave of innovation is beginning to disrupt industry on a global scale. It constitutes a tremendous opportunity for faster productivity growth, but also a potential disruption to a number of economic sectors and to job markets. Academic research and the public debate have focused mostly on the threat that innovation poses to jobs and wages. This paper instead suggests that (i) these same technological disruptions make human capital more important than ever for companies' strategies; (ii) greater attention needs to be devoted to new forms of complementarity between new technologies and human capital. While some jobs will be displaced, the greatest impact of innovation will come in the way that many jobs will be transformed; the evidence to date supports the authors' view that innovation will once again result in more and better jobs—but much work needs to be done to optimize the transition. In particular, more effort should be devoted to (i) understanding what new skills will be needed, and how existing jobs will change; (ii) upgrading education and professional training schemes; (iii) reforming labor market institutions to support a future where a larger share of workers will change jobs and employers more frequently, and more people will work independently in a crowdsourcing or "gig economy" framework; (iv) reforming social benefits systems and bolstering social safety nets to smooth the economic transition and cushion the impact on the worst-affected workers. As innovation disrupts a growing number of industries, human capital strategies will need the collaboration of companies, educational institutions, governments and multilateral policy agencies. This paper presents an analysis of the challenges, addresses the key areas of action, and puts forward some specific proposals, including policy actions, industry initiatives, and further research projects. The authors argue that the G20 could and should champion a comprehensive approach to leverage digital-industrial innovations for faster job creation and growth, with measures to re-align demand and supply of skills, labor market reforms, redesigned social safety nets, measures to promote digital innovation and facilitate the adoption of skills-augmenting technologies. Private sector companies should strengthen training programs. International cooperation, standards harmonization and interoperability will be essential to maximize the benefits and minimize the disruptions—the G20 can therefore play a key role.

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Authors

Marco Annunziata, Annunziata + Desai Advisors, annunziata.sf@gmail.com

Hendrik Bourgeois, General Electric Company; Cargill

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Introduction

The global macroeconomic environment today seems characterized by greater uncertainty than ever before. The massive disruption of the Global Financial Crisis has been followed by an unprecedented monetary stimulus by major central banks—extraordinary in its size, shape and duration. The normalization of monetary policy has just begun, and has already started to send waves of volatility through financial markets. Rapid economic growth in emerging markets has brought about a significant rebalancing in the global economy, upsetting traditional equilibria, displacing workers in some advanced economies industries, and fueling protectionist pressures. Technological innovation has accelerated, disrupting a growing number of industries, while at the same time productivity growth decelerated sharply across OECD economies. Prominent economists have questioned the validity of long-standing theoretical frameworks and policy tools.

This also carries unprecedented uncertainty for labor markets across the globe. Many governments have achieved a remarkable degree of success in boosting employment levels following the Global Financial Crisis: the US and Japan are back at full employment—in fact, in the U.S. there are now fears of overheating, unemployment rates have declined substantially across Europe, though they remain elevated in some countries, and large emerging markets keep creating employment opportunities for their fast-growing populations.

This success, however, has been accompanied by growing concern about the quality and sustainability of job creation. Even as labor markets tightened, the pace of wage growth has remained muted, fueling fears that a rising share of new jobs might be “low-quality” service sector occupations providing only low incomes and limited career opportunities. More recently, we have seen some first signs of stronger wage growth in the U.S., but not in itself sufficient to quell concerns about the quality of new jobs.

At the same time, the accelerated pace of innovation brings a new set of challenges. In advanced economies, technological change has already displaced some sections of the workforce, though global competition and, in some cases, market rigidities have also played an important role. In emerging markets, the possibility of automation poses a rising threat to low-cost, low-skill workers. The potentially disruptive impact of technology on jobs features prominently in the media, most often with alarmist headlines, and contributes to feed insecurity in the workforce, particularly among those categories of workers who have experienced very slow wage increases so far. In addition, technology driven impacts on labor markets are fueling populist political reactions, prone to blame and oppose liberalization, trade, immigration, and free markets.

Fear that technology will create massive unemployment is not new. In the early 19th century, workers in France would throw their wooden shoes, called “sabots” (clogs) in the newly introduced textile machines to break them so to preserve their employment. Allegedly, this practice lies at the origin of the word ‘sabotage’. In the coming years, however, technological innovation is likely to have a much more significant impact on the workforce. We are in the early stage of a digital-industrial revolution, as new digital technologies are beginning to transform industries: traditional industrial assets become intelligent interconnected devices, new production techniques like additive manufacturing revolutionize the way we design and build

products, the widespread use of sensors and big data transforms the way that work is carried out on factory floors and in many other sectors of the economy, including the services and agricultural sectors for instance. Advances in robotics and artificial intelligence will further propel this transformation.

These changes have already fueled concerns that innovation will cause permanent mass unemployment and a significant further widening of income inequality. Bill Gates recently argued that it might be desirable to slow the pace of innovation; others have advocated the adoption of Universal Basic Income schemes (Delaney, 2017). In 2016, the European Parliament proposed a report which considered the need to introduce corporate reporting requirements on the extent and proportion of the contribution of robotics and AI to the economic results of a company for the purpose of taxation and social security contributions (Delvaux, 2016).

Yet the evidence runs counter to the prevailing narrative that new technologies are already causing job losses on a massive scale. As mentioned above, employment levels have risen strongly, while labor productivity growth has slowed to a near stand-still across the OECD since the financial crisis, the opposite of what the simplistic automation narrative would suggest.

The risk that new technologies will displace jobs, and potentially eliminate some of the current categories of employment, has to be taken seriously. There is in fact a very high probability that technological unemployment will rise in the coming decades. In addition, we do have to consider the risk that—even as new jobs are created—technological displacement might result in a *net* loss of jobs for a period of time. More importantly, the nature of many occupations, the way in which many jobs are performed, is likely to change significantly. We believe that more attention and study need to be devoted to the way in which jobs are likely to change, and to what steps can be taken to facilitate the transition and to build the right supply of skills. This includes addressing the current demand for skills, and trying to build a bridge to the future and different skills demand.

The U.S. manufacturing sector provides significant evidence of a skills mismatch: there are numerous reports of companies struggling to find qualified employees for specific skilled factory floor positions (Mutikani, 2017), and the aggregate data show a widening gap between job openings and hires in manufacturing. Similar challenges have emerged in Australia (Burgess, 2017) and other countries. This suggests that the main risk is not widespread automation and rising unemployment, but rather a growing mis-match between the skills demanded by a rapidly evolving economy and those supplied by an education system that struggles to keep pace.

We believe that throwing sands in the wheels of innovation would be misguided and counterproductive. Innovation remains the key to sustained economic growth and rising living standards. We also believe that technological change will ultimately result in more and better jobs—as it always has in the past. Accordingly, rather than slowing it down, we should continue fostering and enabling innovation, and stay ahead of the curve by anticipating technological changes that are bound to occur. This time, however, it will be even more important to manage the transition effectively, because this new digital dimension promises to make innovation in

industry faster and more disruptive than in the past. This will require action on two fronts: (a) measures to enable the employment- and wealth-creating potential of new technologies; and (b) measures to cushion the social impact of inevitable transitory disruptions.

The digital-industrial revolution is already changing the demand for skills that the workforce needs to succeed in manufacturing and other areas of economic activity. Moreover, to capitalize on this revolution and turn it into a competitive advantage, it is important to better prepare the workforce to promote the quick absorption of this new technology in the economy. The challenge ahead is to understand this evolving trend and design a system of education and training able to endow workers with the necessary abilities, and to equip our economies with the appropriate flexibility and support mechanisms to allow companies, workers and societies to adapt quickly and successfully to the faster and deeper changes in front of us.

Technology's Impact on Jobs: Understanding the challenge

During the past 10-15 years, a number of academics and practitioners have analyzed the impact of technology on jobs. While research on the topic has made significant inroads, we believe we are still far from a satisfactory understanding of the trends and of how they can be managed.

Most of the academic literature begins by focusing on the concept of “task” —recognizing that jobs involve the combination of a number of different activities. A first strand of the literature divides task in “routine” and “non-routine”. Routine tasks are defined as activities that can be well described by a codified set of instructions. By their nature, these are more likely to be successfully executed by a computer—in the case of “cognitive” tasks—or by a robot—in the case of “manual” tasks.

Autor et al. (2003) show how a decline in jobs involving routine manual and cognitive tasks became apparent in the 1980s and had continued since. They also note a stabilization in the number of jobs involving non-routine manual tasks, that is jobs that require interpersonal interaction, situational awareness and the need to respond flexibly and rapidly to changes in the environment. Autor and Price (2013) confirm an increase in these jobs starting about 2000. Both studies also show a stabilization in the number of non-routine cognitive tasks, those requiring managerial or analytical skills; though Autor and Price note a marginal decline between 2000 and 2006, followed by a modest rebound through 2009.

These studies and others confirm an intuitive insight: computers and other machines are usually better than humans at repetitive tasks in a controlled environment; when we can, we tend to delegate those tasks to the machines.

Frey and Osborne (2017) take the argument one step further. They note that thanks to advances in Artificial Intelligence (AI) and Machine Learning (ML), machines no longer need to be given step-by-step instructions in order to perform a task—they can learn by themselves just by absorbing enormous amounts of data on how a task is performed. Frey and Osborne cite self-driving cars as a case in point. The task of driving a car in varying conditions is way too complex to be described by a set of instructions, and self-driving cars were once considered science fiction. Today they are a reality.

Artificial Intelligence could therefore greatly expand the range of tasks that will be taken over by machines. Frey and Osborne take a detailed look at the universe of existing jobs in the U.S., based on the Bureau of Labor Statistics classification. They assume that advances in AI and ML will proceed at the same pace as in the recent past, and from there infer which tasks are likely to be automated in the coming years (Frey and Osborne do not give a definite time scale, but a couple of decades is seen as a plausible horizon). They conclude that 47% of existing U.S. jobs are at high probability of becoming automated (where high is defined as 70% or higher).

The Frey and Osborne study is probably the most widely quoted, but it is not the only one to give a dismal picture of future employment trends: A recent PwC study (Berriman and Hawksorth, 2017) estimates that 38% of U.S. jobs are at high risk of automation; other advanced economies fare little better, with 35% of jobs at risk in Germany, 30% in the U.K. and 21% in Japan. The World Bank's 2016 World Development Report estimates that 57% of jobs in OECD countries could be automated in the next two decades. Taken together and at face value, these studies paint an extremely alarming picture, suggesting that between one-third and one-half of existing jobs across advanced economies will be eliminated by technology within a fairly short time span.

A simplistic reading of studies like Frey and Osborne's tends to equate a job's share of tasks that are at risk of automation with the probability that the entire job will be automated—this interpretation has unfortunately dominated the public debate. This misses the more complex and nuanced relationship between human abilities and technological capabilities:

- There will be jobs where over 50% of the tasks can be automated, but the minority share of tasks that cannot be automated is crucial to the nature of the job itself; this could lead to a situation where the worker keeps the job, outsources some of the tasks to the technology, and takes on additional—in some cases more interesting and rewarding—tasks that become part of the reconfigured job description in a way that need not imply any job loss.
- In other cases, the automation of a share of the tasks might instead lead to a consolidation of responsibilities and a reduction in the number of jobs. To take a simple example, suppose a situation where two-thirds of the tasks in a job are automated and a worker is then able to perform the work previously carried out by three workers. This could lead to a direct reduction in headcount by two-thirds; which could however be compensated by the attendant improvement in competitiveness generating additional demand.

Moreover, to put these fears of mass unemployment in perspective, consider that (1) these new technologies have already been gaining traction for several years; and (2) researchers have been drawing attention to its impact for nearly twenty years now. The job-displacing impact of new technologies should therefore be already visible. Yet, as we noted above, employment levels have risen across a wide range of countries, including those closest to the technology frontier.

Acemoglu and Restrepo (2017) develop a model where robots and humans compete, and compute a measure of “exposure to robots” to estimate the impact on employment and wages in different industries and commuting zones. They estimate that robots have displaced between

360,000 and 670,000 U.S. jobs between 1990 and 2007. While this number was immediately picked up in alarmist tones by the press, the data show that over the same period the U.S. economy created on a net basis about forty times the top-range estimate of those taken by robots. Aware of this, Acemoglu and Restrepo (2017) concede that “...the number of jobs lost due to robots has been limited so far...” but argue that this is because “...there are relatively few robots in the U.S. economy...” and that a plausible scenario would see both the number of robots and the number of jobs lost accelerate significantly in the future.

Other research, however, points to a different conclusion. A recent paper by Graetz and Michaels (2017) analyzes the impact of robots on jobs across a sample of seventeen countries; they find no evidence of a negative impact on overall employment levels, though they do find an adverse effect on low-skilled workers. Building on their analysis and dataset, Andes and Muro (2015) point out that countries that use robots more intensively appear to have suffered a smaller loss of manufacturing jobs than less robot-intensive countries.

The assessment of the impact of technology on jobs is complicated by the fact that labor markets in the U.S. and other advanced economies have been impacted by other concomitant shocks, most importantly an acceleration in global trade flows with increased competition from China and other emerging markets. A parallel strand of the academic literature has endeavored to assess the impact of trade on jobs.

Autor et al. (2013) analyze U.S. commuting zones to assess the effect of exposure to Chinese imports; they estimate that competition from Chinese imports accounts for 44% of the decline in U.S. manufacturing employment between 1990 and 2007; in the more recent part of the sample, 2000–2007, they estimate that 55% of manufacturing jobs lost were displaced by Chinese imports. They find that local labor markets more exposed to China’s competition also experienced a decline in labor force participation as well as an increase in disability benefits and other transfers over the 2000–007 period. Caliendo et al. (2015) estimate that nearly one third of the U.S. manufacturing jobs lost between 2000 and 2007 (800,000 out of about 3 million) were displaced by competition from Chinese exports to the U.S. (though they also note that cheaper imports of Chinese intermediate inputs and consumer goods were instrumental in fueling a similarly-sized jobs growth in other sectors of the economy).

This review of the literature suggests that we are far from a satisfactory understanding of the impact of new technologies on jobs. The main takeaways, in our view, are:

1. The evidence available to date supports the idea that innovation will lead to stronger overall job creation in the long run, by boosting economic growth and purchasing power and enabling the rise of new jobs. This is consistent with the historical experience of the past two centuries.
2. Some categories of jobs have already been displaced, however, and others are at risk (truckdrivers threatened by autonomous vehicles are an obvious example). Wider sections of the workforce will be impacted as technology changes the way that their jobs are carried out and the tasks they involve.
3. Innovation will continue to change the distribution of available jobs across industries, the types of jobs available and the skills required. This disruption is set to accelerate

with the faster adoption of robotics, artificial intelligence, and additive manufacturing—just to name three prominent new technologies impacting industry.

An increasing number of *tasks* will be automated or modified by new technologies; this holds the key to a better understanding of how jobs will change. The McKinsey Global Institute has recently published two in-depth studies (Manyika et al., 2017a and 2017b; see also Chui et al., 2016) that focus on how jobs will change, rather than on a simpler risk-of-automation metric. The studies warn that while on balance—and on average through the economic cycle—affected economies should be able to maintain full employment, the magnitude of the labor market transformation ahead represents a formidable challenge.

A strategy to cope with this challenge, we believe, should be guided by a collaborative research effort involving not just universities, think tanks, and government research institutions, but also companies drawn from different areas of technology, manufacturing and services, as well as national and international policy institutions. Further research needs to go down “into the trenches”, to understand how existing job functions are already changing; which technologies are proving most helpful to workers on the factory floors, and what individual characteristics or training programs make workers more or less successful at adapting to the new technologies.

This research could help improve awareness and provide both companies and governments with a common baseline to share best practices, laying the ground for a coordinated—and therefore more effective—policy and awareness effort. G20 policymakers could play an important driving role. At the policy level, this could also help promote common standards in the measures to adopt to benefit from new technological developments ensuring interoperability across markets where needed. These new technologies are based on platforms, ecosystems and collaboration frameworks—international cooperation, standards harmonization and interoperability will be essential to maximize the benefits and minimize the disruptions. It could also provide the basis for a more constructive public awareness campaign, steering the public debate away from sterile alarmism while equipping students and workers with tools to better understand the challenge ahead and prepare for it.

Human talent as the crucial resource

The focus in both the research and the public debate tends to be on the threat that new technologies will displace human labor—and as we argued above, this risk needs to be taken seriously. But the faster pace of innovation also places human capital front and center of corporate strategies, as companies will face new and changing requirements for talent:

- Some of these technology changes require new skills because they result in the convergence of different disciplines: digital-industrial innovations will require a mix of traditional mechanical skills and new software skills.
- Some of the new manufacturing techniques require a new way of thinking: additive manufacturing can bring maximum benefit only if products are designed in new ways. This can often be best achieved by product designers whose thinking has not been shaped by the traditional manufacturing methods.

- Since changes in technology and business models are reshaping the competitive landscape, companies can now benefit from ‘cross-over talent’: people who have work experience across a variety of different fields
- As changes in technology and business models become faster and less predictable, companies need greater flexibility in tapping and deploying talent.

This is happening at the same time as technology breakthroughs show the potential to alleviate the constraints on some traditional resources, such as energy. And at the same time as some industries face the challenge of an aging workforce, with large cohorts of experienced workers set to retire in the next decade; while education and training systems struggle to keep up with innovation.

Talent will therefore be the scarce resource of the future, and the ability to tap and deploy the right talent will be a key factor of success.

Skills-augmenting technologies

While the public debate has focused on the risk of technologies displacing workers, on the “race against the machine” view, innovation has already generated a number of new skills-augmenting technologies that can augment the efficacy and productivity—as well as the safety—of workers at different levels of the skills distribution; and they can facilitate and accelerate the learning of new skills on the job as well as the transmission of knowledge and expertise across the workforce.

An especially powerful example is the development of upskilling technologies: portable and wearable digital devices that can augment the abilities of workers at different levels of the skill distribution, and that are already being deployed on factory floors. For example, augmented-reality smart glasses can be used in manufacturing and field services to provide workers with just-in-time step-by-step instructions on how to perform specific procedures. Such devices can give workers instant on-the-job training, and allow them to tap the support and accumulated expertise of their colleagues.

These upskilling devices have already been deployed by industrial companies, for example by General Electric in its Renewable Energy and Healthcare divisions. Abraham and Annunziata (2017) show that the use cases so far have demonstrated an average productivity improvement of over 30%; and the improvement can be realized already from the first use and with almost no need for prior training.

These upskilling tools are especially powerful when combined with software analytics able to provide a much more sophisticated view of the functioning of industrial equipment—from an individual electricity generation turbine to an entire power plant—and advise technicians and management in real time on alternative courses of action. Artificial Intelligence tools will prove increasingly powerful in providing clear information on the technical and economic trade-offs of specific decisions (for example the intensity of use of a piece of power generation equipment

at a precise point in time based on demand and supply on the grid as well as overall market pricing).

Other striking examples of welfare-enhancing digital technologies can be found in many sectors, including the agricultural sector, with the introduction of software that can identify cows by their hide patterns and faces, and track key data such as food and water intake, heat detection and behavior patterns; the software then delivers analytics that drive on-farm decisions that can not only positively impact farmers' tasks, milk production, reproduction management, but also overall animal health.

These innovations are part of a broader wave of digital innovations in manufacturing, which includes the concept of a “digital thread”, the ability to link workers and equipment through sensors and analytics, and to link the manufacturing floor to supply chains and distribution networks. This results in a greater ability to predict and to react to changes in market conditions. It can yield significant increases not only in efficiency and productivity, but also in workplace safety and other benefits.

As upskilling technologies such as these develop and advance, policymakers should devote increasing attention to their efficacy, and to their impact on employment and wages; they should also analyze the feasibility and desirability of measures targeted to incentivize and accelerate the adoption of skills-enhancing technologies; this could speed up the integration of new technologies in a way that would benefit both workers and overall productivity. A coordinated approach to these measures would help not only to promote best practices, but also to offset the risk that they might fuel international tensions in the current environment of rising protectionist pressures. At the same time, companies will need to review and update their operational and management practices, in order to exploit the full potential of the new technologies; they will also need to rethink their human capital strategy, around a better understanding of the evolving skills and talent needs, and redesigning strategies to attract, train and retrain talent.

Education and training

As we discussed in the previous sections, we need to gain a better understanding of how technology will continue to change existing jobs, and of the new jobs it will create. As the picture becomes more detailed, we can better understand what skills will be best suited for the new economy. Just as in the case of robotics and automation, the public debate on education and skills often veers towards extreme positions:

- some argue that the future will only have jobs for computer and data scientists, and that education should therefore be heavily skewed towards Science, Technology, Engineering and Math (STEM);
- others say the future calls for a new breed of highly creative “Renaissance Man” (and Woman, as thankfully gender equality has progressed since the fifteenth century), and that education should emphasize creativity and problem—solving skills.

Both ideas hold an important grain of truth, but both seem to take it to an unrealistic and possibly counterproductive extreme. It is worth remembering, for instance, that not every citizen of Renaissance Florence was a polymath—most held regular jobs as bakers, merchants or accountants. There is little doubt, however, that the education system is proving increasingly inadequate to keep pace with the accelerating economic transformation.

Building the right skills for the future will certainly require greater emphasis on STEM. As we have argued above, workers stand to benefit from the introduction of new technologies in the workplace. An increasing number of new opportunities, however, will hinge on workers' abilities to understand and interact with new technologies. This does not imply that most workers will need degrees in engineering or computer science, or will all have to be coders—upskilling technologies will be increasingly accessible thanks also to improvements in user interfaces. But it does mean that workers will need to acquire a greater degree of familiarity and comfort with new technologies. **The bar on scientific and digital literacy needs to be raised.** We should think of scientific and technological literacy as the new basic literacy. In most countries, the idea that every individual should be equipped with basic reading and writing skills has long been accepted (though some would argue that excessive reliance on portable devices is chipping away at these educational gains...). It should now be extended to include basic knowledge of science and technology.

While young people's attitudes to science cannot be changed overnight, governments should urgently take concrete measures to ensure that a greater proportion of the workforce is equipped with STEM skills. These measures could include:

- a) implementing decisive curriculum reforms,
- b) creating strong fiscal incentives for companies to partner with schools and universities,
- c) developing active labor market policies with training for unemployed to tackle STEM shortages, accompanied by more Vocational Education Training in STEM.

The education system should also renew its efforts to nurture creativity, critical thinking and problem-solving abilities:

- across industry and other economic sectors, decision-making is becoming increasingly data-driven; advanced analytics and Artificial Intelligence provide workers and managers at most levels of the organization additional powerful tools; it becomes all the more important for workers to be able to fully leverage the potential of these new tools, and this requires the ability to correctly frame the problem and the most effective approach to a solution. Similarly, managers need to think about how to address problems and develop strategies in light of the new information made available by digital technologies, and the insights that can be gleaned from these data.
- Creativity and critical thinking are emerging as characteristics that have a very high degree of complementarity to the most advanced technologies in robotics, AI and others. High performance in these dimensions would therefore allow workers to display high productivity, which would be reflected in higher compensation.

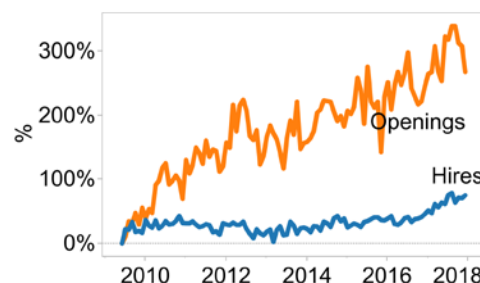
At the same time, **countries need to redouble their efforts to increase the supply of traditional manufacturing skills. Vocational education, apprenticeships, and company-provided training programs can all play an important role.** This is especially important because of evidence that even as employment levels remain lower than desired, companies in a number of countries are having difficulties filling job vacancies for lack of qualified candidates. In the U.S., for example, this “skills gap” is highlighted by the growing divergence between the number of job openings and the number of hires (Figure 1).

A 2015 report by the US Manufacturing Institute and Deloitte projects that as many as 2 million US manufacturing jobs will remain unfilled in the coming decade due to an insufficient availability of skills (Deloitte and the US Manufacturing Institute, 2015).

This skills gap is set to widen because of demographic trends. In a number of important industrial sectors, ranging across oil and gas, transportation, electricity generation and distribution, and others, large cohorts of senior and experienced technicians are due to retire within the next decade, and there is no comparable pipeline of younger workers ready to take their place, sometimes also given the physical hardships of specific professions. Many operators in these sectors consider this to be one of their key strategic challenges. This challenge could be met in part with new technologies that can upskill workers, automate the hardest and most dangerous tasks, and make it easier for younger and less experienced workers to tap the reservoir of experience created by their senior colleagues: for example by creating easily accessible online libraries of instructions and how-to videos that can rapidly guide workers through complex procedures that they have not encountered before. At the same time, though, industry leaders need to see that the required supply of skills is gradually being rebuilt. Unless these remedial actions are put in place, companies operating in these sectors might face an overpowering incentive to develop and adopt technologies that will replace the exiting workforce, eliminating attractive job opportunities.

Addressing this problem requires acknowledging that traditional technical abilities in, among others, electrical and mechanical skills remain of fundamental importance even as new digital technologies transform the work environment. Encouraging a closer dialogue and cooperation between the education system and the world of industry can play a fundamental role, helping to

Figure 1. Manufacturing Openings & Hires.
Seasonally adjusted, change since June 2009



Source: US Bureau of Labor Statistics

shape a system of vocational education and apprenticeships that provides a rapid and targeted path to high quality jobs. The German system already provides valuable examples in this respect. G20 governments could pool their efforts and share best practices on how to improve the communication and cooperation between education and industry. This should ideally include a more transparent way to inform students about the prospective careers and likelihood of employment for different educational paths.

While experimentation at the national and local level will help identify the most effective education models and strategies, this is an area that could benefit from an internationally coordinated effort to:

- i. Set common standards for STEM curricula that can guide individual governments' education reforms efforts; convergence towards common standards would also facilitate the mutual recognition of skills that could in turn enable better worker mobility.
- ii. Coordinate a cross-country analysis of the existing gaps in traditional manufacturing skills. In most countries, evidence of skills gaps remains anecdotal. It would be greatly beneficial to have a coordinated effort to understand the true extent of the existing need for both engineering and non-college educated technical skills. This could then inform education reform efforts.
- iii. Commission an assessment of the efficacy of vocational and apprenticeship programs implemented in key countries, with the intent of identifying best practices as well as possible further improvements. Individual governments would then be able to adopt the programs best suited to their individual challenges.

Private sector companies should not stay on the sidelines, and can act both through increased investment in training programs and with efforts to improve gender balance and promote more women in engineering and technical roles. Improving the gender balance, especially in technical roles, can have substantial benefits in terms of better performance and competitiveness for individual companies, and faster economic growth and job creation at the macroeconomic level. Annunziata and Chase (2017) highlight these benefits and argue that improving the gender balance will be fundamental to realize the full growth-enhancing potential of new digital-industrial innovations.

Labor market policies, life-long learning and social safety nets

Countries where labor markets remain characterized by rigidities, and with a high cost for companies to attract talent, will not be able to leverage the full job-creating potential of new technologies.

It is worth noting in this respect that the EU countries suffering from the highest youth unemployment rates are not the ones experiencing faster rates of technological development and adoption. Moreover, youth unemployment rates in these countries have remained at extremely high levels for the last forty years, as shown in Annunziata (2012); this suggests that in these

countries at least, structural rigidities play a much larger role than technology in reducing job opportunities and preventing younger generations from accessing jobs and career opportunities. Eliminating these rigidities should be a priority; left unaddressed they would render ineffective all other efforts to boost employment.

More entrepreneurial and flexible forms of work that will be increasingly enabled by new technologies will likely play a very important role in improving the functioning of labor markets. Digital-industrial innovations lower the threshold for becoming self-employed and engaging in entrepreneurship. At the same time, new technologies allow for more flexible and agile work because more people are now better connected and can be set up for digital work through home offices. These new forms of employment offer a real answer to unemployment, and can open up a new set of opportunities especially for younger workers. Access to this type of work should be encouraged and facilitated, rather than regarded as a threat or a last resort. New manufacturing technologies such as Additive Manufacturing (or ‘3D printing’) could open the way for a new generation of ‘hardware startups’ and a new sector of high-tech artisan activities, similarly to what we have seen already in the software space. Affordable 3D printers could play the same democratizing role as affordable personal computers.

The rapid pace of technological change also implies that workers are likely to face two new trends:

First, the tasks composition of jobs and the skills required to perform them are likely to keep evolving at a faster pace than in previous decades; if that is the case, workers will have to update their skills and familiarize themselves with new technologies and applications at a higher frequency than in the past—even as they remain in the same job.

Second, both the changing nature of jobs and the more pervasive disruption of industries imply that workers mobility will probably increase, with a higher share of workers changing jobs and employers with higher frequency, and more people working independently in a crowdsourcing or gig-economy framework. **Indeed the last decade has already witnessed a significant rise in the share of non-traditional work arrangements.** A recent study by Larry Katz of Harvard and Alan Krueger of Princeton finds that the number of contingent workers has increased by about one half over the past ten years, to 16% of the U.S. workforce by 2015 (Katz and Krueger, 2016). The increase is equivalent to the entire net rise in employment over that period. On a broader definition, the Fed Board’s Enterprising and Informal Work Activity Survey (EIWA) finds that over one third of the U.S. adult population relied on informal paid work as a complement or substitute for traditional work arrangements (Robles and McGee, 2016). The McKinsey Global Institute estimates that 20-30% of the working age population in both the U.S. and Europe engages in “independent work”, defined as work with a high degree of autonomy, based on a short-term relationship, and compensated by task, assignment or sales (Manyika et al., 2016).

Gig-style work arrangements allow a wider range of people to find work opportunities that can match their personal preferences and the constraints of their personal lives. They can therefore improve labor force participation—as noted by Fed Board Governor Lael Brainard—bringing a wider range of talent into play (Brainard 2016). Hall and Krueger (2017), for example, found

that three-quarters of Uber drivers reported the greater flexibility and control over their schedules as a significant benefit of the work arrangement.)

Non-traditional work arrangements are only starting to spread to manufacturing: Katz and Krueger find that the manufacturing sector accounts for a mere 6% of the employees engaged in alternative work. But they are likely to account for a growing share of manufacturing employment in the decades ahead.

Adapting to this new reality will require a number of actions on the part of policy makers, industry and the education sector:

Countries should strive to develop more robust frameworks for life-long learning. These might in principle include (i) ongoing in-house training programs run by individual companies to keep their workers up to speed with the new technologies being deployed and facilitate the transition of workers to different opportunities within the company, where possible; (ii) professional training programs organized by educational institutions to allow workers to upgrade their skills or acquire new skills either when they are in between jobs or while they are engaged in full-time or part-time employment; (iii) training and education programs run jointly by consortia of companies—either in the same industry or cutting across industries; this would allow different companies to contribute a wider set of expertise, while at the same time forming a pool of workers that the entire consortium could then tap into.

In other words, the changes afoot will likely **call on companies to look at human capital as both a joint resource and a joint responsibility. Policymakers have an equally important role to play:**

This should be complemented by a system of sufficiently robust, flexible and portable social benefit systems. In some countries, notably in the U.S., this would require a fundamental rethinking of the existing social benefits system setup.

Employment legislation should also better reflect the rapidly changing nature of the world of work. International policy institutions could design recommended guidelines to help national governments adapt labor market and other legislation and rules that were originally designed for a completely different phase of industrial and economic development. Allowing businesses to better adapt to shifting demand will in turn further promote innovation and entrepreneurship and provide increased employment opportunities, particularly for young people.

Labor market reforms should be complemented by national and international-level efforts to facilitate the flow of workers across countries. While this seems to run counter to the current political climate, a sufficient degree of labor mobility is essential to enable the efficient allocation of talent, allowing countries to more easily and quickly address skills gap, and allowing workers to seek the best job opportunities and to pursue training and career development opportunities.

EU Member State governments could take the lead on this front, and set the example by working together to eliminate barriers and adopt measures to promote the flow of workers across the EU. These include

- (a) providing for equivalence in national social security and pension programs, and
- (b) adopting programs that incentivize young workers to seek employment outside of their home country.

A greater degree of international labor mobility could be fostered through specific measures, which could include:

- i. Mutual recognition of educational and professional qualifications meeting internationally recognized standards
- ii. Points-based visa systems for highly qualified workers
- iii. Permanent and time-bound visa and work permit programs for low-skilled workers.

Stronger education and training policies will equip workers with the right skills needed to keep pace with new technologies; and more flexible and open labor markets would help workers to more quickly identify and secure the job opportunities best suited to their abilities and personal circumstances and priorities. But they will not be able to negate the adverse transitional impact of technological disruption. In the short term, some jobs will be automated; some workers will see their skills become obsolete; some companies will be disrupted by new competitors and forced to downsize or exit the market outright. Workers will be impacted. And what economists can define as “short term” in the context of an overall economic transformation can be a very long term for an individual whose livelihood and place in society are put at risk.

It will therefore be imperative to **rethink, redesign and strengthen social safety nets** to better cope with faster and more profound technological transformations. A stronger social safety net will make it easier for displaced workers to retrain and re-skill more rapidly; this will not only reduce personal hardship, but also improve a country’s overall human capital, contributing to economic growth. A stronger social safety net will also make it easier for individuals to take more risk in their education and employment choices, in an environment characterized by greater uncertainty and where individuals will need to exercise greater entrepreneurship in shaping their careers. Moreover, by cushioning the adverse impact of innovation on the workforce, a stronger social safety net will buttress social and political stability and reduce the risk of a fierce backlash against technology—similar to the backlash against globalization that has already affected economic policy decisions in a number of countries.

Designing better social safety nets should start with a better understanding of how workforce disruption will most likely manifest itself. While there is no scarcity of research on the impact of automation and digitization on employment, there is as yet limited clarity on which sections of the population are most likely to be affected—beyond the broad insight that low-skilled workers in routine jobs are most at risk. A better understanding of where the impact is likely to be most severe, in terms of both social groups and geographies, would help design more targeted cushioning measures, but also anticipate the potential political backlash and the attendant impact on policy-making efforts.

It would be highly desirable for international policy institutions to coordinate an international study mapping the potential impact of technology on jobs onto different socio-demographic characteristics of the populations, so as to better understand the socio-economic ramifications,

which are likely to extend well beyond job losses. This study would provide the basis to design upgraded targeted mitigating measures; these could include:

- (a) Retraining and career-counseling programs, designed so as to be targeted at the most at risk segments of the population;
- (b) Time-bound unemployment benefits programs, fine-tuned to yield the right combination of support and incentive for a rapid re-entry into the labor force;
- (c) Long-term income support mechanisms for workers who might find it prohibitively hard to re-enter the labor force—notably specialized workers disrupted at a later stage in their careers;
- (d) Support measures for small and medium sized companies and their employees, to enable them to access retraining measures otherwise limited to large companies.

Here as well, EU countries could play a leading role: the European continent has a long tradition of strong social safety nets, and this uniquely positions Europe to ensure that particularly the short term social cost to technology advance are managed effectively. Europe's multi-layered political structure could also provide a useful testing ground to design and deliver policies at the appropriate level—central, regional or local.

New financing strategies to enable R&D

Last but not least, an important challenge in many countries is to design and promote new-generation funding programs for digital-industrial innovative projects. Many countries with a robust level of fundamental research activity are nonetheless lagging behind in developing products and solutions that digitize manufacturing assets and increase manufacturing productivity. Europe is a case in point. One notable exception is France, that has since some time successfully operated an attractive system of tax credit towards investments in R&D. G20 countries and the EU overall should resolutely opt for increased resources in their R&D funding programs, both as a percentage of the total budget and in absolute figures.

Allocating sufficient public funds is only part of the challenge. Equally important is designing programs that can

- i. leverage additional funding sources, with private sector participation, including possibly new forms such as crowdfunding, and enacting legislation that can facilitate the creation of venture capital investment
- ii. identify appropriate targeting strategies that can ensure funds are efficiently allocated to the best opportunities.

These programs should recognize that innovation projects will be subject to a higher degree of risk than traditional public infrastructure projects. Funding programs should therefore be designed with a view to allow for a 'natural' rate of project failure, but in such a way that failures can be identified at an early stage, reducing the capital expense. Private sector best practices would provide a useful blueprint in this respect.

Conclusion

In this paper we have argued against the current dominant focus on the threat that new technologies pose to jobs and wages, suggesting instead that these same innovations are making human capital ever more important in companies' strategies, and that we need to give greater emphasis to understanding and leveraging the new complementarities between technology and human skills. A combined effort by governments, private companies and education institutions—informed by additional research—could not only ensure that innovation will once again ultimately result in more and better jobs, but also smooth the transition and cushion the impact on the most affected sectors of the workforce. This paper represents an effort to identify the key areas for action and suggest some initial specific measures and initiatives. It underscores that G20 countries and policymakers are well-positioned to play a crucial driving role in this transformation.

References

- Abraham, M., Annunziata, M. (2017). Augmented reality is already improving worker performance. March 13, 2017. Harvard Business Review.
<https://hbr.org/2017/03/augmented-reality-is-already-improving-worker-performance>
- Acemoglu, D., Restrepo, P. (2017). Robots and jobs: evidence from US labor markets. March, 2017. NBER Working Paper No. 23285. <http://www.nber.org/papers/w23285>
- Andes, S., Muro, M. (2015). Don't blame the robots for lost manufacturing jobs. April 29, 2015. Brookings Institution.
<https://www.brookings.edu/blog/the-avenue/2015/04/29/dont-blame-the-robots-for-lost-manufacturing-jobs/>
- Annunziata, M., Chase, K. (2017). Engineering the future: the socio-economic case for gender equality. Available at:
http://dsg.files.app.content.prod.s3.amazonaws.com/gereports/wp-content/uploads/2017/02/09140658/Women_in_Tech_White_Paper_2.61.pdf
- Annunziata, M. (2012). Wasted youth. 14 May, 2012. voxeu.org. <https://voxeu.org/article/wasted-youth>
- Autor, D.H., Levy, F., Murnane, R.J. (2003). The skill content of recent technological change: an empirical exploration. November 01, 2003. *The Quarterly Journal of Economics*, Vol. 118, Issue 4, 1279–1333. <https://doi.org/10.1162/003355303322552801>
- Autor, D.H., Price, B. (2013). The changing task composition of the US labor market: an update of Autor, Levy, and Murnane (2003). June 21, 2013. <http://economics.mit.edu/files/11661>
- Autor, D.H., Dorn, D., Hanson, G.H. (2013). The China syndrome: local labor market effects of import competition in the United States. October, 2013. *American Economic Review*, Vol. 103, No. 6, 2121–68. <http://dx.doi.org/10.1257/aer.103.6.2121>
- Berriman R., Hawksworth, J. (2017). 4—Will robots steal our jobs? The potential impact of automation on the UK and other major economies. UK Economic Outlook, March 2017, PwC-UK.
<https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf>
- Brainard, L. (2016). The “Gig” economy: implications of the growth of contingent work. November 17, 2016. Board of Governors of the Federal Reserve System.
<https://www.federalreserve.gov/newsevents/speech/files/brainard20161117a.pdf>
- Burgess, M. (2017). Too much education, not enough skills causing youth unemployment. November 27, 2017. News.com.au.
<http://www.news.com.au/finance/work/too-much-education-not-enough-skills-causing-youth-unemployment/news-story/1de627be83c2f4bb369b619f44f3d900>
- Caliendo, L., Dvorkin, M.A., Parro, F. (2015). Trade and labor market dynamics: general equilibrium analysis of the China trade shock. Federal Reserve Bank of ST.Louis.
<https://doi.org/10.20955/wp.2015.009>
- Chui, M., Manyika, J., Miremadi, M. (2016). Where machines could replace humans—and where they can't (yet). July, 2016. McKinsey Global Institute.
<https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/where-machines-could-replace-humans-and-where-they-cant-yet>

- Delaney, K.J. (2017). The robot that takes your job should pay taxes, says Bill Gates. February 17, 2017. qz.com. <https://qz.com/911968/bill-gates-the-robot-that-takes-your-job-should-pay-taxes/>
- Deloitte Consulting LLP and the Manufacturing Institute. (2015). The skills gap in US manufacturing 2015-2025 outlook. Deloitte. <https://www2.deloitte.com/us/en/pages/manufacturing/articles/boiling-point-the-skills-gap-in-us-manufacturing.html>
- Delvaux, M. (2016). Draft report with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL)). May 31, 2016. European Parliament. <http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML%2BCOMPARL%2BPE-582.443%2B01%2BDOC%2BPDF%2BV0//EN>
- Frey, C.B., Osborne, M.A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, Vol. 114, Issue C, 254-280. https://econpapers.repec.org/article/eeetefoso/v_3a114_3ay_3a2017_3ai_3ac_3ap_3a254-280.htm
- Graetz, G., Michaels, G. (2018). Robots at Work. February 14, 2018. personal.lse.ac.uk. Available at: http://personal.lse.ac.uk/michaels/Graetz_Michaels_Robots.pdf
- Hall, J.V., Krueger, A.B. (2017). An analysis of the labor market for Uber's driver-partners in the United States. *ILR Review*, first published June 29, 2017. <http://journals.sagepub.com/doi/10.1177/0019793917717222>
- Katz, L.F., Krueger, A.B. (2016). The rise and nature of alternative work arrangements in the United States, 1995–2015. NBER Working Paper No. 22667. <http://www.nber.org/papers/w22667>
- Manyika, J., Lund, S., Bughin, J., Robinson, K., Mischke, J., Mahajan, D. (2016). Independent work: choice, necessity, and the gig economy. October, 2016. McKinsey Global Institute. <https://www.mckinsey.com/global-themes/employment-and-growth/independent-work-choice-necessity-and-the-gig-economy>
- Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P., Dewhurst, M. (2017). Harnessing automation for a future that works. January, 2017. McKinsey Global Institute. <https://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works>
- Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., Ko, R., Sanghvi, S. (2017). What the future of work will mean for jobs, skills, and wages. November, 2017. McKinsey Global Institute. <https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages>
- Mutikani, L. (2017). U.S. job openings hit record high; skills mismatch rising. June 6, 2017. Reuters.com. <https://www.reuters.com/article/us-usa-economy/u-s-job-openings-hit-record-high-skills-mismatch-rising-idUSKBN18X1S7>
- Robles, B., McGee, M. (2016). Exploring online and offline informal work: findings from the Enterprising and Informal Work Activities (EIWA) Survey. Finance and Economics Discussion Series 2016-089. Washington: Board of Governors of the Federal Reserve System. <https://doi.org/10.17016/FEDS.2016.089>

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