HOW THE NEXT WAVE OF TECHNOLOGICAL INNOVATION WILL CHANGE THE NATURE OF WORK, EMPLOYMENT, EDUCATION AND TRAINING

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ABSTRACT

Advances in science and engineering have a profoundly transformative effect on every aspect of our daily lives. Most of these are very positive, improving health, generating wealth, driving development and creating new opportunities. However, as a result of the current pace and breadth of technological development, disruptive effects could become more rapid and frequent. Artificial intelligence could displace most existing jobs, and is already driving a transformation of social and economic systems that is happening ten times faster and at 300 times the scale of the first Industrial Revolution. The challenge, therefore, is to develop the research, education and training programs needed to prepare an entire generation for new modes and models of work. If we do not find viable and economically attractive solutions, then the likely outcome is extreme polarization between a small global elite and an increasingly disadvantaged underclass, with a corresponding increase in the risk of civil unrest, crime and terrorism.

1. INTRODUCTION

Advances in science and engineering have a profoundly transformative effect on every aspect of our daily lives. All of us depend on modern agriculture, energy and water engineering, while medical science now allows us to control many infectious diseases that, in an earlier age, destroyed entire populations. However, many great challenges lie ahead. A combination of demographic growth, rapid development and rising consumption could result in global shortages of food, water and energy, as well as an extensive loss of biodiversity, and accelerate the rate of climate change .

This is a cause for action, not despair, because every major problem stimulates the search for new solutions. The pace of innovation, technological development and change continues to accelerate across a broad front, as a result of dramatic progress in fundamental science, engineering applications and new product development. This is particularly rapid in areas such as biological science, informatics and nanotechnology, where both the fundamental science and the engineering applications are evolving simultaneously, changing basic concepts and perceptions as to what is possible. For example, molecular engineering will enable the manufacture of new materials with previously impossible combinations of lightness, strength, flexibility and other properties, which could lead to applications such as energy-efficient and safe vehicles, space elevator cables, bridges that span unprecedented distances and clothing that incorporates communication and diagnostic electronics. In the biological sciences, there are lines of research that promise the new generations of genetically-specific pharmaceuticals, advanced biofuels, and genetically modified plants and animals that will be needed to support a far larger human population in the decades ahead.

These technological changes will also drive a process of social and economic transformation. As Schumpeter (1942) noted, every major innovation creates new opportunities, demands and markets, but simultaneously renders the old technologies obsolete and the associated skills redundant. So innovation continuously disrupts and restructures the competitive environment, and drives a process of creative destruction, destroying the firms that have lost their markets, which allows the capital and the workforce to be reallocated into the new economic activities. In some instances – such as the move from horse to motor-based transport-entire new industries are created and old ones destroyed. In those countries with a large and diverse economy, the gains are substantial, as resources are continuously reallocated into areas where they generate more value. In countries with a narrow economic base, however, the fortunes of the entire nation can rise or fall accordingly, because there is little capacity to absorb the displaced workforce. This is particularly obvious in nations that depend largely on a single export, such as oil, where a fall in the price can precipitate an economic recession.

As a result of the current pace and breadth of technological development, these disruptive effects could become more rapid and frequent. If, for example, it proves possible to use genetically-modified bacteria to manufacture long-chain hydrocarbons that can then be refined into fuel, this would be very advantageous for the oil-importing nations that could then start to manufacture their own fuel, but countries that currently depend on exports of conventional oil could see their economies shrink sharply. A transition to eco-composites (engineering components made from plant fibers and resins) to replace petrochemicals would hurt the economies of countries that currently export petrochemical feedstocks, but would create major new market

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opportunities for agriculture, especially in sub-tropical regions, which would stimulate investment and growth in countries like Brazil. Investments in large scale solar plant in North Africa could be used to supply European markets, which could make previously unproductive desert regions very profitable. As these examples suggest, every significant technological development of this kind can create both winners (the firms, countries and regions that are well-placed to supply the new markets) and losers (those that see their former markets and exports decline).

So it is clear that the future will be very different from today - hopefully for better, possibly for worse, but certainly different. This creates a profound challenge for many countries. Where is their place in the new world? Will they be able to supply the goods and services that will be required in future? Or are they currently over-reliant on industries that might become redundant?

2. THE IMPLICATIONS FOR NATIONAL DEVELOPMENT STRATEGIES

It is widely agreed that a critically important part of any strategy for national development in today's world is to strengthen scientific and technical capacity, to produce graduates that can create new enterprises and increase the productivity and competitiveness of businesses, and to develop a trained, skilled workforce, because it is believed that this combination will help to stimulate innovation, investment, economic growth and employment. It is, of course, impossible to anticipate all possible future outcomes that could result from the complex interaction of demographics, competition, geopolitics and technological innovation, so some investments will be more successful than others, but this does not invalidate the core strategy of human capital development.

There is now, however, a significant challenge to this approach, which is that the next wave of technological innovation could make many current forms of employment redundant. This would make it necessary to rethink the goals, nature and purpose of many current educational and training systems, as there is little point in training people to undertake tasks that can be done more efficiently and cheaply by artificial intelligence and automated systems.

3. THE IMPACT OF AUTOMATION

Automation has gradually replaced many tasks that were previously done manually. This has allowed the workforce in most countries to migrate from primary to secondary industries, and then into tertiary services. This has transformed labour markets. Until the early 20th Century, most of humanity worked in agriculture, mainly because the relatively low productivity at the time meant that most of the agricultural workforce were not generating large surpluses, and so could not support a large number of people in other sectors. A large modern economy such as the USA, however, has less than 0.5% of its workforce in agriculture. Mechanization has replaced labour, which has generated enormous agricultural surpluses, allowed almost the entire workforce to migrate from the land into other forms of employment, and, thereby, created a vast amount of additional wealth.

It is important to note that this process has, to date, been enormously positive, because the process of innovation and technological development has created far more jobs than it has destroyed. There is no fixed amount of labour in any economy, as people have always found new ways to add value, and create goods and services for which there is a demand.

What is changing, however, is the speed of change itself. The automation of primary industries (such as agriculture) happened over many generations, the automation of secondary industry happened within one or two generations, and neither process is yet complete. The difference now is that the next wave of automation could replace most existing jobs, and do so within just one or two decades. The McKinsey Global Institute estimates that artificial intelligence is now driving a transformation of social and economic systems that is "happening ten times faster and at 300 times the scale, or roughly 3,000 times the impact" of the first Industrial Revolution.

In previous waves of technological change, increasingly diverse jobs were created in new sectors of the economy at a pace that could absorb much of the labour that was being displaced. There are some indications that the next wave will be too swift to allow an easy transition for much of the current workforce. As many formerly middle-class jobs have become unnecessary in the post-industrial societies, many of the people that used to hold those jobs did not move into more highly skilled jobs, but shifted into lower-paid work, mainly because they did not have the training to make the transition to a job at the same rate of pay. This suggests that there is a rapid change happening in terms of the kind of skills that people need, and that the education system is lagging behind the trend and failing to give people the skills sets and adaptability

that are now required. Demand is growing for highly skilled, highly educated workers, but declining for those with low to moderate levels of education, which means that these people are more likely to be displaced downwards or out of the formal economy entirely . For many people, the future will involve doing work that is more interesting and fulfilling than today, using machines to enhance and extend their skills, but for those that are not well-placed to make this transition, the future may look bleak. For many societies, it may become necessary to develop new forms of economic activity with equally unprecedented speed – or else face the risk of rising unemployment, rapidly increasing inequality and potentially serious social dislocation and civil unrest. This problem is likely to be compounded by the fact that while many people expect that the future will involve far more automation than today, relatively few expect it to happen to their jobs. A report by the Pew Research Center (2016) found that most Americans expect significant levels of workforce and job automation to occur over the next 50 years, but that most of today's workers did not think that their own jobs or occupations would be affected; 36% of workers anticipated that their current jobs or occupations would 'definitely' exist in their current forms five decades from now, while another further 44% expected that their jobs would 'probably' exist in 50 years . This means that this group is unlikely to make the necessary investment in retraining.

4. SPEED OF CHANGE

It now appears possible that automation could now rapidly replace most remaining routine tasks while the next wave of development will see information technology systems replace many highly skilled processes, even in areas such as medicine, law and finance. This is being driven by the '4th Industrial Revolution', which involves the integration of previously separate fields such as artificial intelligence, robotics, nanotechnology, 3D printing, genetics and biotechnology. This is likely to introduce a new wave of radical innovations, and destroy 'old' jobs with unprecedented speed. Frey and Osborne (2013) suggested that almost half of the current jobs in the USA could now be automated. Additive manufacturing (with 3-D printers) could replace factories, construction workers and architects.

Online courses could allow universities to operate with far fewer teaching staff, while online services could allow governments to operate with a much smaller civil service. Many of the current generation of low-paid jobs could also be vulnerable; as the former CEO of McDonald's pointed out recently, it is now 'cheaper to buy a $35,000 robotic arm than it is to hire an employee who's inefficient making $15 an hour bagging French fries.' The cost savings will be dramatic. The Bank of America Merrill Lynch predicts that by 2025 the annual savings from the replacement of employees by artificial intelligence will reach US$9 trillion, with an additional cost reduction of US$8 trillion from efficiency gains in manufacturing and health care, and a further US$2 trillion in efficiency gains from the deployment of self-driving cars and drones .

5. THE REVOLUTION IN TRANSPORT

The transport sector provides a good example of the impact of future change. A number of firms are developing driverless vehicles, and a range of countries (including the UK and various states in the USA) have started the process of legalizing their use on the roads. This has revolutionary implications for road transport; it will make it much cheaper, safer and more reliable, mainly by replacing humans. At present, about 75% of the cost of shipping goods by road across the USA is the cost of the labour involved, so eliminating the workforce will reduce the cost by the same percentage. In addition, driverless trucks can work for 24 hours per day, while drivers in the USA are restricted by law from driving more than 11 hours per day (9 hours in the UK). This means that the shift to driverless trucks would double the capacity of the US road network while reducing the cost per load by 75%, giving an eight-fold improvement in the price-performance of ground transportation networks. Automated vehicles are also much more fuel-efficient (as they can be programmed to run at optimal cruising speed), and far safer (on average, over 33,000 people die in road accidents in the USA each year, mostly as a result of human error, so many of those lives could be saved). Similarly, substantial savings will be made in other regions, such as Europe, where over three-quarters of all shipped goods are transported by road.

Shipping represents a significant part of the cost of all consumer goods, so an eight-fold improvement in the price-performance of ground transportation means that consumers everywhere will see prices fall significantly and their standard of living rises commensurately. The impact on employment, however, will be equally dramatic. About 1.6 million people in the USA work as truck drivers, which is about 1% of the workforce, and most of them would then become redundant, along with many of the jobs in support activities such as local deliveries, gas

stations, diners and motels; a total of nearly 9 million people in the USA who would lose their current jobs .

6. THE TRANSITION FROM OWNERSHIP TO ACCESS

Another defining future trend is that the need to own a physical device to obtain a particular service will be removed by the servicisation of the economy. For example, Airbnb has become the world's largest hotel chain without ever owning a single hotel room. Similarly, many people no longer own their music recordings because they can now use services such as Spotify and YouTube to access whatever track they want to hear, whenever they want.

This model has already extended to mobility. One of the first working models, called Car2Go, was developed in the city of Ulm, Germany, in 2008 . Users were given mobility on demand, without the need for ownership, maintenance costs, insurance or any other asset management requirements. They can now take a car whenever they need one, use it for as long as they want, and leave it at a nearby drop-off point. In addition, the cars are fitted with diagnostic systems; this allows maintenance schedules, inventories of spare parts and so on to be optimized. This is far more efficient, much cheaper and more convenient than individual car ownership – and may eventually remove the need for most people to ever own a car. Similarly, Uber is rapidly destroying the business model for taxis. These effects will be compounded by the transition to driverless cars, which will eliminate the need for both public transport and private car ownership.

These examples illustrate several aspects of the transition away from the ownership of physical goods to access to services. It is clear that many consumers no longer require ownership if they want to enjoy a service, but the intensity of use is typically much higher, dramatically improving efficiency. At present, most cars are parked for 95% of the time , representing a very inefficient commitment of capital, but removal of the need for ownership could reverse that ratio.

These innovations will generate extraordinary efficiency gains, but will also make car salesmen, driving instructors, car insurance salesmen, car park attendants, traffic police and many other associated jobs unnecessary.

7. JOBS THAT MAY DISAPPEAR

There are a number of jobs that are now clearly vulnerable to automation. These include most office jobs, data handling, logistics, tax and auditing, secretarial and accounting positions, as data and text processing and accounting are increasingly being replaced by software, receptionists, cashiers, bank tellers, airline check-in staff and postal services, as most of these tasks can be replaced by electronic communications and self-service points, couriers, who can be replaced by better e-document security and secure electronic signatures, government bureaucrats, who can be replaced by better online systems and integrated databases (this is already happening in countries like Denmark and Estonia); paralegals, who can be replaced by semantic analysis software that can determine relevance and precedents; farmers, some of whom can be replaced by automated hydroponic systems and tissue-culture meat protein; security guards, some of whom can be replaced by inferential analysis software that can identify suspicious content or pattern of behaviour; and even many medical services, which can be replaced by expert diagnostic systems. Fighter pilots are being replaced by Unmanned Combat Aerial Vehicles (UCAVs), computer chip designers are being replaced by software, and many manufacturing operations (including construction) are likely to be replaced by 3-D printing. All jobs that depend on information asymmetries are vulnerable, as information asymmetries are disappearing in on-line markets. These include realtors, who can be replaced by searchable GIS systems that list titles and permit sales and secure transfers, brokers, who can be replaced by automated transactions and travel agents, who can be replaced by software that knows personal preferences and searches for best routes, dates or prices.

8. THE IMPACT IN DEVELOPING COUNTRIES

Developing countries too will be profoundly affected. For example, over half of all jobs in Angola, Mauritius, South Africa and Nigeria, up to 85% of all jobs in Ethiopia and almost 90% of the 400 million jobs in low-income countries could be now be automated. This means that the traditional path to growth (which involved moving workers from agriculture to more productive jobs in factories) may not be available to today's low-income countries. This means that they will have to find new development pathways.

9. ADAPTING TO CHANGE

It is clear that these trends will have a transformative effect on economic structures and on work and

employment. How can countries prepare for such profound change?

A new commitment to human capital development is likely to be part of the solution, as skilled jobs are less susceptible to automation, but this requires a coherent strategy for change. As noted earlier, there is no point in investing in skills in an area that is about to become redundant. In general, jobs that require originality, social and creative intelligence, perception of irregular spaces and manipulation are very difficult to automate and are, therefore, at low risk of replacement in the near future. These areas do not, however, provide the kind of mass employment opportunity that can create livelihoods for millions of people. Some countries are now considering whether a basic income scheme (a guaranteed income for all citizens) will be necessary to prepare for a world in which many conventional forms of employment will cease to exist, but this will be politically difficult unless it can either be restricted to citizens (Switzerland recently rejected a basic income scheme because of concerns that it would encourage immigration), or else is introduced universally, which would not be feasible for low-income countries.

The profound challenge facing the world, therefore, is to identify new growth areas and to develop the research, education and training programs needed to prepare an entire generation for new modes and models of work. If we do not find viable and economically attractive solutions, then the likely outcome is extreme polarization between a small global elite and an increasingly disadvantaged underclass, with a corresponding increase in the risk of civil unrest, crime and terrorism.

This suggests that the workforce will have to be far more mobile and flexible in future, and that it will be increasingly important to anticipate or respond positively to change. The challenges therefore include the following:

- How can people be prepared for jobs that may not exist yet?
- What will be the new industries and business opportunities?
- Which jobs could disappear?
- What jobs will be required in future?

10. THE ROLE OF EDUCATION AND TRAINING IN DEVELOPMENT

It is also essential to reconsider the role of educational and training institutions in national development; traditional 'supply-push' models of the role of educational systems in developing countries have largely ignored both the larger economic context of global change and the need to foster innovative capacity.

Educational and training systems have a crucially important role to play in supporting and enabling a transition to a skill-based economy. They cannot, however, drive this process. The distinction becomes clear when considering the failure of traditional strategies for education and training, which have tended to focus on increasing the supply of skilled and educated people into the workforce. There is little evidence, however, that the process of economic development can be directly supply-pushed by education and training. For example, an oversupply of over-qualified graduates in an economic recession can lead, instead, to a situation where many university graduates are unemployed or underemployed, and consequently disaffected, or emigrate in search of better opportunities overseas .

The evidence rather suggests that education is demand-pulled by economic development. As economies strengthen and diversify, they assume the inverted pyramid shape of a mature economy (in which tertiary service sectors increasingly dominate secondary processing and manufacturing sectors, which in turn increasingly dominate primary mining and agricultural sectors). As this happens, the demand for a widening range of increasingly diverse, specialist and sophisticated skills expands, which thus expands the range of opportunities and demands for educational courses. The development of India's ICT industry, for example, was made possible by the availability of a large number of underemployed mathematics graduates, but these graduates would probably have remained underemployed had it not been for the Indian Diaspora in California, who provided the link to markets, ideas and business opportunities that demand-pulled subsequent developments, as well as the investment capital and technology-transfer that triggered and accelerated the subsequent rapid growth.

This raises a number of fundamental issues. For example:

- Can the educational and training systems in developing countries make a stronger contribution to economic development? Should available resources be focused on areas where there is potential demand-pull? Given the long lead-time

required to develop new courses and produce the first graduates, is it possible to identify these areas in advance? Which areas will generate the future employment opportunities, and what are the associated training needs?
- Which elements of funding for research, education and training should have priority if demand-pulled training is to succeed? What are the implications for resource allocation? Where do schools, colleges, universities and adult training agencies fit into this process? Where are the key entry points for effective intervention?
- Is it possible to support the development of increasingly knowledge-based economic activities by encouraging entrepreneurship in knowledge and service-based economic activity – particularly in countries and sectors with a relatively thin skill base in those areas?
- What are the implications of rapid technological change for generating new employment opportunities - and destroying redundant business activities?

11. ANTICIPATING THE FUTURE

The further we look into the future, the less we know for certain about it. This means that we have more scope to shape development trajectories towards our preferred outcomes. It also means that our forecasts are more likely to be wrong. However, the real choice for most countries is to either engage constructively with the global trends, or to be driven by decisions made by others, with all the negative implications that will have for the domestic economy and the local skill-base. In effect, this is a choice between taking part in the process of change, or else becoming increasingly powerless. The critical success factors are likely to include:

- Understanding the possible future pathways;
- Developing a strategy for the transition;
- Developing the skills that will be needed in the years ahead, and disseminating these skills into the workforce.

CONCLUSION

The next wave of technological innovation and change is likely to have a particularly rapid and extensive effect on economic structures and on the nature of work and employment. Many new jobs will undoubtedly be created, but a far larger number of current forms of employment are likely to become displaced, at least in the short term. This could create enormous social problems unless there are large-scale programs to adapt educational systems to help people prepare for profound change. This is likely to involve a focus on jobs that require originality, social and creative intelligence, as these are difficult to automate and are at low risk of replacement in the near future, but these activities are unlikely to provide mass employment opportunities. The profound challenge facing the world, therefore, is to identify new growth areas and to develop the associated research, education and training programs needed to prepare an entire generation for new modes and models of work.

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