



The Future of Work in the Developing World

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The digital economy has been expanding at an accelerating pace over the last decade. In the process, it has begun to transform an increasing share of our economies. Its disruptive impact in consumer-facing sectors is well known, and has already triggered lively reactions and a nascent policy debate on whether new policy measures and regulations are needed.

Over the last few years the digital revolution has begun to extend into the industrial world. The coming together of digital technologies and industrial activities is happening along several dimensions: the ability to collect and process “big data” generated by industrial machinery and processes; automation and robotics; new, digitally-driven manufacturing techniques; data-driven changes in factories’ workflow, supply chains, and distribution channels; extended forms of cooperation and collaboration, including crowdsourcing in industrial innovation.

At General Electric we have called this new wave of industrial innovation “the Future of Work.” It is driven by three interrelated and mutually reinforcing trends:

1. “**The Industrial Internet**,” which merges big data with big iron, integrating cloud-based analytics with industrial machinery, resulting in greater efficiency and reduced downtime;
2. “**Advanced Manufacturing**,” which weaves together design, product engineering, manufacturing, supply chain, distribution, and servicing into one cohesive intelligent system, delivering greater speed and flexibility at lower costs;
3. “**The Global Brain**,” the collective intelligence of human beings across the globe integrated by digital communication, resulting in crowdsourcing, open collaboration, and a much faster pace of innovation.

The Industrial Internet is the merger of software and hardware, of big data and big iron, with the integration of cloud-based analytics with industrial machinery. The rapid decline in the




price of electronic sensors today makes it cost-effective to equip industrial machines with a large number of sensors that enable them to analyze their environment, react, and interact with each other and with us. At the same time, lower costs of storing and processing data allow us to harvest massive amounts of data from industrial equipment and to process it with increasingly advanced analytics, generating insights on how to operate them more efficiently—both individual machines and entire systems.

For example, data collected from jet engines lead to new insights on how to modify takeoff and landing behavior as well as engine maintenance, so as to reduce jet fuel consumption for each engine and aircraft. In wind power generation, industrial Internet solutions allow the wind turbines on a farm to communicate with each other and respond in a coordinated way to changes in environmental conditions: as the force and direction of the wind changes, the turbines can modify the pitch of their blades in a coordinated manner to maximize power output for the entire wind farm, as opposed to every wind turbine optimizing its own output in isolation.

The Industrial Internet allows us to shift from reactive to preventive maintenance, fixing machines before they break. This can dramatically reduce unplanned downtime and raise the efficiency of individual machines as well as entire systems, reducing delays in hospitals or air traffic, and increasing the efficiency of power distribution. Greater data availability allows us to predict with a high degree of confidence when a machine is likely to malfunction and why; companies can then schedule preventive maintenance and reconfigure their operations around it, instead of being faced with a disruptive unexpected equipment failure.

The second driving force is **Advanced Manufacturing**. At the core of advanced manufacturing is a digital thread that links together design, product engineering, manufacturing, supply chain, distribution, and remanufacturing (or servicing) into one cohesive and intelligent system. This encompasses new production techniques like additive manufacturing, or “3-D printing,” which allow us not only to create completely new parts and products with new properties, but also to accelerate the cycle of design, prototyping and production. Engineers today can “print” a prototype, test it, adjust the digital design as needed and reprint an improved version—all using the same additive manufacturing machines. This translates into increased speed and flexibility of production, at lower costs. Moreover, the digital thread connecting all aspects of the manufacturing process also allows real-time adjustments to the production process and to supply and distribution logistics. In a “brilliant factory” equipped with advanced manufacturing technologies, engineers and managers can build detailed virtual simulations of how factory floor workflow would need to be changed to introduce a new product, and of how to react to potential sudden disruptions of specific points in the supply chain.




The third driving force is the **Global Brain**: the collective intelligence of human beings across the globe, integrated by digital communication networks. Many of us take for granted the ability to cooperate seamlessly with colleagues in different locations via email, cloud-based file sharing platforms, tele- and video-conferencing. Today, open-source platforms and crowdsourcing are quickly emerging as the most effective ways to unleash the creativity and entrepreneurship potential of the Global Brain. Individual companies are starting to gain expertise that extends well beyond their four walls, accessing a larger pool of talent which can vary depending on the problem at hand. Companies gain flexibility. Workers gain greater entrepreneurial control over their skills and talents. The Global Brain will redefine the relationship between employers and employees, to the benefit of both. The process will be magnified as global economic growth brings to millions more people both connectivity to the Internet and the time to take advantage of it. Better access to clean water, food, and health care will free up precious hours, while improving health and longevity.

To get a sense of the potential benefits of the Global Brain, consider the example of GE's jet engine bracket challenge: in 2013, GE partnered with the crowdsourcing platform GrabCAD and challenged the community of engineers to provide an alternative design for the bracket used to attach jet engines to the aircraft body. New designs should be manufactured with 3-D printing techniques, and be lighter than the existing part, and at least as strong. The winning design was an eye-opener: submitted by a young engineer in Indonesia who had no prior experience in aviation, the design was stronger than the original and reduced the weight of the part by 84 percent. This was a powerful example of how tackling a challenge with the support of people with different backgrounds and experience can quickly result in innovative solutions.

The innovations of the Future of Work are turning traditional industrial assets into interconnected devices, full-rights members of the Internet of everything. They are also changing the nature of economies of scale, and blurring the lines between manufacturing and services. Industrial companies that learn how to combine the digital and the physical can **unlock new value for both customers and shareholders**.

This value derives primarily from unprecedented gains in productivity and efficiency, leveraged on a large scale. **Industry represents about one-third of global economic output**, with manufacturing accounting for between 15 and 20 percent. The scale of global industrial operations implies that even small efficiency gains translate into substantial aggregate economic gains. Indeed, the industrial Internet is a key driver of the projected growth in the total number of interconnected "things," **expected to reach some 50 billion by 2020**.

In 2012 we estimated that just a 1 percent efficiency improvement would yield \$90 billion savings in the oil and gas industry over a 15-year period; over \$60 billion each in the power industry




and the health care industry, and about \$30 billion each in aviation and in rail transport. These sectors and others will benefit from the higher speed, reduced unplanned downtime, and lower fuel burn that the industrial Internet can bring—ultimately resulting in higher profitability. Our estimates of 1 percent efficiency gains show the benefits that even marginal performance improvements can bring to industry, but in practice the benefits are already turning out to be significantly larger: in wind power generation, industrial solutions yield a 5 percent increase in annual power generation for a single wind farm; in rail transportation they yield 10 percent reductions in fuel consumption and 10-20 percent increases in velocity over the network.

Digital-industrial innovations are also blurring the lines separating industry and services, extending their efficiency gains well beyond the boundaries of the industrial sector as traditionally defined. An interconnected industrial machine becomes inextricably connected to the digitally enabled services it can provide. This has very powerful implications. Companies will need to adapt their commercial strategy—no longer selling physical assets and, separately, maintenance, repair, or consulting services, but rather selling integrated solutions delivered through a combination of connected machines and software applications. Trade policy will need to move away from its current separate focus on goods on one side and services on the other.

Advanced manufacturing will redefine economies of scale and lead to the democratization of manufacturing. New techniques like 3-D printing are beginning to enable economically efficient production on a much smaller scale, and allow a single production facility to manufacture a range of different items thanks to the greater flexibility of additive manufacturing. This could trigger the rise of a new artisanal class as creative and entrepreneurial people gain access to these more powerful and flexible manufacturing tools. It can also bring more flexibility in the localization of manufacturing facilities. We could see a more distributed system of smaller factories positioned to get access to specific talent, or to more competitive energy supplies, or to more attractive markets. At the same time these manufacturing facilities would be able to leverage the input of people in remote locations on a flexible basis, thanks to the Global Brain.

Leveraging the full potential of this wave of innovation is not easy, however. Innovation is disruptive, and this faster-paced innovation will be even more so. For both companies and countries it represents as much of a challenge as an opportunity. It requires significant investments. It requires the development of new capabilities, concentrated in the areas of data science, software and cloud computing, user interfaces, and cybersecurity. These new capabilities in turn need to be melded with traditional scientific and engineering capabilities.

It will have painful short-term costs in segments of the labor market, as some jobs will be displaced and some skills made obsolete. This impact will need to be cushioned with appropriate



support measures. There is an intense debate on the ultimate impact that this new wave of innovation will have on employment and wages. Some experts have taken a very negative view, arguing that, while previous technological innovations have ultimately resulted in more jobs and higher wages, this time it will be different. They argue that we might have reached the point where intelligent machines can take over so many of the tasks performed by humans, and that more and more workers will find themselves without any marketable skills. I disagree. I think this negative view dramatically underestimates the ingenuity, creativity, and entrepreneurship of people. I believe this new wave of innovation will also result in more and more rewarding jobs. We are seeing evidence of this already in industry, where industrial Internet innovations are augmenting the capabilities and productivity of workers at all skill levels.


It will be important, however, to invest more in creating the skills of the future. This means raising the bar on science, technology, engineering, and mathematics education, because the technological content of the economy is increasing. It means establishing closer links between the education system and industry, to better align supply and demand for skills. It means leveraging digital tools in education to an even greater extent, to broaden access to education. And it means investing more in lifelong learning, including with a greater commitment by companies to provide ongoing on-the-job training to help workers keep pace with new technologies.

This digital revolution in industry has powerful potential implications for global development

The democratization of manufacturing and shift towards microfactories can help developing economies accelerate the growth of their manufacturing sectors. Smaller scale production facilities can position themselves as suppliers to existing larger entities in countries or regions that currently rely on just one or two industries—as in the case of commodity-rich countries. This would allow diversification of the manufacturing base and the creation of more localized supply chains and ecosystems, which could fuel a faster build-up of skills.

More broadly, the accelerating pace of digital-industrial innovation can help developing economies leapfrog existing technologies and more quickly gain competitiveness in the global marketplace. The relatively low-capital stock in developing economies is an advantage in this respect, as it creates the opportunity for faster installation of new generation equipment. Mobile banking and distributed power generation and distribution systems are examples of digital innovations that are helping developing countries bypass or remedy their current infrastructure gaps.

The new innovations can also help developing economies address some of their specific challenges. Health care is one example. Developing economies have a higher share of rural population, and need to extend the reach of their health care system to remote areas in order to increase



population coverage; this needs to be done while facing a scarcity of doctors, nurses, and qualified technicians. New digital innovations enable remote monitoring of medical equipment, so that from central monitoring locations expert technicians can help less qualified personnel in remote clinics to bypass technical problems, and doctors can help with remote diagnoses. These solutions have already been launched in China. Energy efficiency and sustainability is another area where the cost savings and productivity gains afforded by new technologies can provide precious help.

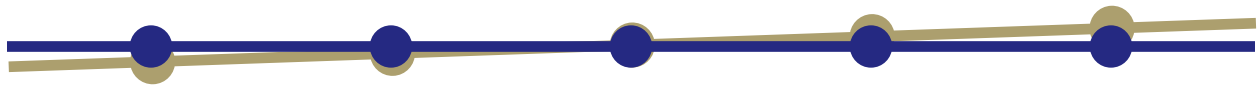
At the same time, developing economies face additional challenges in leveraging the opportunities of new technologies.

Perhaps most important is the current shortage of skills and the relatively weak state of education systems in a number of developing economies. This should be urgently addressed in order to create the pipeline of skills required by new technologies. Digital innovations themselves can help address this problem, as they can increase learning opportunities even in the face of limited school infrastructures and a limited number of teachers. A few experiments have already been successfully launched in Africa, for example.

While new technologies can help bypass infrastructure gaps, reaping their full long-term benefits will require a substantial investment in basic infrastructure, notably power, transportation, and digital communications.

Companies looking to engage more with developing-world workers and customers also face a new set of opportunities, which require a corresponding shift in business models:

- New technologies can help develop new products that more closely match the needs of lower-income customers in developing countries. In health care, these innovations have already yielded portable ultrasounds that allow pre-natal checks in remote locations at lower costs; and infant incubators using incandescent light bulbs as a source of heat, again reducing costs.
- Developing these tailor-made solutions requires more localized research and development involving more local engineers and scientists; sometimes only people deeply steeped in the local culture will have the intuitive understanding of the needs and constraints that should guide the design of the right solution.
- Companies also need to build a broader local workforce, including at managerial levels, to contribute to the growth of a local middle class that is needed to put economic development on a sustainable basis. This requires a greater effort on the part of companies in terms of on-



the-job training and skill transfers; and probably a greater engagement in helping the growth of the local education system in a way that is aligned to future demand for skills.

- Finally, companies will need to be especially sensitive to the priorities of governments that in developing economies are trying to address different basic priorities with limited resources: creating jobs, improving health care, and access to power and clean water. There needs to be a closer dialogue so that governments and companies can address these challenges in partnerships. Otherwise, the risk is that governments will be more tempted to resort to protectionist measures—ranging from trade barriers to local content requirements—that will ultimately slow the adoption of new technologies and economic growth overall.

We are at the onset of a new industrial revolution which will bring tremendous benefits. We should all work together to put in place the right conditions and safeguards to make the transition as smooth as possible and accelerate the pace at which the benefits can accrue to the largest number of people.

Marco Annunziata is Chief Economist of General Electric, which provides financial support for Brookings.