ROBOTLUTION

THE FUTURE OF WORK IN LATIN AMERICAN INTEGRATION 4.0

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THE FUTURE OF WORK IN LATIN AMERICAN INTEGRATION 4.0

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HYBRID INTEGRATION

TRADE 4.0

AN (IM)PERFECT FUTURE?

DIGITAL INCLUSION

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CUTTING-EDGE THOUGHT

More than 40 experts from around the world have put forward their ideas on the future of work and integration 4.0 in Latin America

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Being Prepared

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In the 21st century, the Fourth Industrial Revolution is generating structural changes in trade and employment, just as the technological revolutions of the 19th and 20th centuries did. New technologies like the Internet of Things, cloud computing, artificial intelligence, blockchain, or 3D printing, to name just a few, are changing the way that we produce and trade goods and services as the digital economy becomes increasingly hyper-connected.

The Internet of Things is enabling new trade networks and improving the efficiency of supply chains. Barriers to entry are coming down, the market is expanding, and the scope of integration policies is growing. Technology has brought us new ways to monitor shipping and cargo safety, guarantee product quality, and optimize route planning to bring costs down while making deliveries more efficient and improving customer relations.

Cloud computing and big data have led to positive transformations in storage logistics and trade through postal services. They play a key part in real-time analysis of shipping, thus reducing accidents and economic losses due to merchandise being spoiled or lost. Artificial intelligence and automation can increase productivity and incentivize reshoring, but there are many questions around their impact on trade, employment, and social equality. While some jobs are being automated, new professions are appearing and new skills are changing and updating traditional jobs.

Blockchain cuts down on intermediaries, improves inventory management, and reduces risk analysis work at customs facilities. Similarly, 3D printing can transform how and where we produce autoparts, vehicles, machinery, medical instruments, and clothing, among other goods. These are just a few examples of the new technological trends in economic integration that this issue examines in detail.

We are living at a watershed moment, a time of structural change when the countries of Latin America need to position themselves to take advantage of technological progress while adapting their trade policies and approaches to training human resources to this more challenging context.

This issue of *Integration & Trade* explores the ties between breakthrough technologies and our trade and employment matrix. It invites us to become better prepared so that Latin America and the Caribbean can benefit from the changes that lie ahead.

The Opportunity Mindset

MARCELO CABROL
Manager, Social Sector
Inter-American Development Bank

Many people view the advent of the Fourth Industrial Revolution with great concern, particularly because of its potential effects on the more vulnerable sectors of our society. Perhaps because I'm a born optimist, I believe that this revolution will also bring huge opportunities for the economies of Latin America and the Caribbean.

It is true that we still lack the financing and public policies we need to build suitable innovation ecosystems. Our countries are far from becoming entrepreneurial states like Israel or South Korea. Many of our firms function as monopolies or oligopolies and have no incentives to innovate. As if that weren't enough, our educational model does not foster entrepreneurial abilities, creativity, or thinking differently, qualities which will be key in the jobs of the future.

However, if the past is any indicator of the future, automation will not necessarily lead to a drop in the share of people who work, but rather to a transformation in which many jobs (particularly the more routine ones) will be destroyed and other new ones will be created, many of which we can't even imagine yet. To prepare for this new world, we need to provide our young people with training in digital skills (coding, creating social networks for business and trade, or analyzing big data), while also helping them to develop social skills to handle emotions, and area where humans still have a clear competitive advantage over robots (at least for now). Developing leadership skills, initiative, and responsibility will also be key as these are now crucial in the labor market and will only become more important as robots replace the more mechanical and repetitive aspects of our work.

These transformations will bring enormous opportunities in sectors such as renewable energy or biotechnology, sectors in which the race is only just beginning.

I believe that, with the right combination of reforms, strategic investments, and skill development, the countries of Latin America and the Caribbean have an opportunity not just to create new business ventures but also to close their inequality gaps. What we need to do now is to change our mindset: it's time to set uncertainty aside and start thinking about opportunities.

A Sociotechnological Contract for Latin America

GUSTAVO BELIZ
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Will robots create, displace, or destroy jobs? How will accelerated automation affect integration and trade in Latin America? These are the two key questions that exponential technologies are posing. Robotization is about transforming our productive matrix in the light of the Fourth Industrial Revolution, but we also need to guarantee that technological changes improve social equality.

To successfully respond to this challenge in one of the most unequal regions on earth, where next-generation smartphone users coexist with a third of the population who eat only one meal a day, we need to align public and private efforts into an innovative, inclusive institutional architecture.

Robots are advancing on our daily lives through artificial intelligence and digitization, which are still in their early days. However, we have yet to organize anticipatory, proactive strategies to harness technological developments to change the course of poverty and inequality in Latin America. That should be our aim. We should be trying to combine advanced knowledge and science with a conscience, deploying our energies in different fields to forge a sociotechnological contract for Latin America.

In different parts of the world, many individuals and institutions have already pointed these needs out. This is not about dragging out tired clichés from sci-fi movies: these are serious opinions from internationally renowned academics and major players in global governance.

Howard Gardner, one of the fathers of cognitive research, has argued: "When we hand important decisions over to digital creatures, or when these artificially intelligent beings stop following the instructions they have been programmed with and rewrite their own processes, ours will no longer be the dominant species on the planet."

A few months ago, the Vatican's Pontifical Academy of Sciences held a high-profile workshop on artificial intelligence. One of the questions it asked was an unsettling one: "could a machine be endowed with an artificial consciousness?" The British Parliament has also called on experts to draft guidelines on how to best adapt artificial intelligence to the world of work. Nick Bostrom, director of the Future of Humanity Institute at Oxford University, has said: "Artificial superintelligence is potentially the best or worst thing ever to happen to humanity." The opinions of TED conference curator Chris Anderson (Brockman, 2015) are provocative: "'Us versus the machines' is the wrong mental model. Like it or not, we're all—us and our machines—becoming part of it: an immense connected brain. Once we had neurons. Now we are becoming the neurons." Alec Ross (2016), another expert on the issue, says: "The next generation of robots will be mass-produced at declining costs that will make them increasingly competitive with even the lowest-wage workers."

Even the singer Peter Gabriel (Brockman, 2017) has something to say on the matter: "It now seems inevitable that the decreasing cost and the increasing resolution of brain scanning systems, accompanied by the relentless increase in power of computers, will take us soon to the point where our own thinking might be visible, downloadable, and open to the world in new ways. The last year has witnessed robots building bridges and houses, but these currently work from 3D blueprints. Soon, we will be able to plug in the architect directly and with a little bit of fine-tuning, see her latest thoughts printed and assembled into a building that same day. The same goes for film and for music and every other creative process." This last reflection takes us the point where transhumanism collides with the singularity, both of which propound infinite technological progress perhaps even to the point of achieving human immortality. But it may also come up against resistance to change and anarcho-primitivism, which is calling for a boycott of the changes that technology brings (Barlett, 2015).

Does Latin America have anything to say about these technological developments? Can we help bring sensitivity, productivity, and humanity to these exponential changes? Few corners of our labor market and aspects of our productive integration will be left unscathed, regardless of whether they involve great intellectual sophistication or low technical skill.

To better understand these phenomena, in this issue of *Integration & Trade*, we examine the future of work and Integration 4.0 in Latin America and the Caribbean. We have set out to provide a broad set of tools for measuring the impact of these changes, analyzing the different sectors involved, and assessing alternative prospects to predict how new technologies will impact employment and regional integration. By bringing together the expert voices included in this publica-

The platform is essentially about transforming our productive matrix in the light of the Fourth Industrial Revolution

tion, we hope to contribute to consolidating an agenda that brings together different breakthrough ideas for successfully transitioning to a digital economy.

This issue contains the work of over 40 experts from different parts of the world, who analyze the risks that automation may pose to work and how this may affect integration and employment. The issues they cover have a common theme and range from the novelty of TechPlomacy to the new agenda for international trade negotiations that focuses on labor standards and disruptive innovations, or from big data applications in glocal governance to cloud computing and the sharing economy.

ARE THE ROBOTS RISING? THE URGENT NEED TO FINE-TUNE OUR METRICS

In the Fourth Industrial Revolution, changes happen at the speed of light. Disruptive technologies allow us to create new markets out of thin air, making some goods and professions obsolete as they are replaced by state-of-the-art tools. Companies are trying to prepare to satisfy new needs, and educational systems are trying to keep up with the often frenetic pace of new skill requirements.[1]

The automation of employment poses some big questions. The International Federation of Robotics estimates that by 2017 there will be over 1.3 million industrial robots operating in factories around the world, a process which the automotive, electronic, and metallurgy industries are spearheading. Only 27,700 of these are in Latin America and the Caribbean. Around 75% of them are concentrated in just five developed countries—of these, South Korea, Germany, and Japan have the highest concentrations of robots per industrial worker.[2]

Although these figures do not include the impact that robots are having on the perennially hard-to-measure service sector, we need to fine-tune the metrics we use to analyze this phenomenon.

There is an ongoing debate around the right method for predicting the risk of automation. Different methodologies yield wildly varying results: some form the basis for prophecies of an impending apocalypse while others support descriptions of technocratic utopias. The differences between these views are vast. From Oxford University, Frey and Osborne (2016) argue that the risks are high and may affect as much as 85% of some sectors and countries. Other authors break occupations down into specific tasks and only use single-digit figures.[3]

Firmly in the latter camp, the International Federation of Robotics (2017) claims that four new jobs will be created for each job lost to technological unemployment and that this explains why "countries with the highest robot density, notably Germany and Korea, have among the lowest unemployment rates."

Kaplan (2016) explores the impact that robotics and artificial intelligence will have on our lives and argues that the robots are rising but they are not coming to get us simply because there is no "them": robots are not people and there is no convincing evidence that they will ever have real feelings.

One thing is certain, many jobs will be lost and many that would have been unimaginable until recently will

We need to align public and private initiatives through innovative institutional architecture

be created. The WEF (2016) predicts that 65% of children who are currently in elementary school will do jobs that do not exist yet.

A NEW CONNECTOGRAPHY FOR GLOBAL VALUE CHAINS

When it comes to trade and integration, the automation of jobs may transform global value chains and encourage reshoring because workers could be replaced by robots. This process, together with a certain disenchantment with the recent results of globalization, may mark the beginning of the end of decentralized production and global value chains that connect nerve centers all over the world.[4]

At least half of all US companies with annual sales of over US$10 billion are thinking of bringing their factories back home.[5] By reshoring their production centers, companies would bring down their transportation costs, be closer to consumers, and respond better to their needs. These new schemes may allow companies to manufacture made-to-measure designs for each client that can be delivered in a matter of days or even hours.

But the opportunities that automation may bring are tangled up with challenges. There are clear advantages: automation reduces accidents, improves working conditions, reduces or eliminates high-risk jobs, increases productivity, brings down costs, boosts economic growth, and may even have a positive effect on trade in key sectors in the Latin American economy, as I will explore in this article.[6] At this early phase, bilateral trade is growing by 2% for each 10% increase in robot numbers in the countries in question. Automation is leading to productivity hikes on a similar scale, at least in the automotive sector, the industry with the largest numbers of robots globally.

This is sparking initiatives to capture foreign currency in Latin America not just in traditional economic sectors but also in knowledge-based services and newer or less established areas, such as FinTech, biotech, cyber security, online payment systems,[7] service robotics, e-commerce, renewable energy, and green tech job, such as forest management or recycling, a sector where new activities are creating jobs at a rate of 9% per year, three times higher than the growth rate for traditional jobs.[8]

The flipside of all this is that automation is also threatening to take technological unemployment to unprecedented levels. A substantial share of exports and employment in Latin America and the Caribbean are concentrated in activities that run the risk of being automated, such as labor-intensive manufacturing, natural resource extraction, and medium-skill services such as accounting, legal, or management services.[9]

Large numbers of occupations are at risk, including many white-collar jobs. Unskilled jobs are not the only ones being automated: sophisticated but routine tasks are also being affected.[10]In the last 10 years, the

Perhaps it's time to start thinking about collective bargaining processes between workers and business owners that include technological innovation clauses

highly educated people working as librarians, translators, or travel agents have seen employment drop by more than 20%. Engineers, mathematicians, lawyers, and accountants, along with other office workers in the public and private sectors, are not immune to these changes.[11]

Other professions will need to transform and acquire new skill sets if they are to keep going. One good example is transportation, a sector of the economy which is crucial to the region's physical connectivity. Each year currently sees 273,000 accidents involving trucks in the United States, causing 3,800 fatal victims and US$4.4 billion in merchandise losses. Within 10 years, there will be two million driverless trucks on the roads that will follow predefined routes and will be controlled by GPS systems from control centers thousands of miles away.[12] We will need to redefine what it means to be a truck driver as this job becomes more like what data analysts do than a what 20th-century truck drivers did.

Logistics is already being revolutionized by Amazon, Google, and start-ups that are using drones to deliver packages. Goldman Sachs (2016) predicts that around US$100 billion will be invested in the drone sector over the next four years. They are already being used in everything from the military to trade, construction, agriculture, insurance, and infrastructure inspection. Over the next decade, the industry will generate 100,000 jobs and US$82 billion.

Working life within companies will also be transformed through rapid "cobotization" (humans and robots working alongside one another, as is already happening in the automotive industry) and substantial upturns in productivity, as the ILO (Méda, 2016) has anticipated. Within Latin America, Brazil and Mexico are already spearheading this process.

According to Gans (2016), there are two ways to handle technological disruption: successfully (Fujifilm, Canon) or disastrously (Blockbuster, Encyclopaedia Britannica). The best recipe for being in the first group is to not underestimate the impact of new technologies, to reinvent yourself quickly, and, above all, to keep your eyes wide open.[13] How can integration strategies improve conditions for us to tackle the changes that lie ahead?

TECHPLOMACY FOR INTEGRATION 4.0

Latin America and the Caribbean needs to rethink its long-term development strategy. The hopes that were invested in commodities have not paid off and local economies continue to suffer due to their vulnerability to the price cycles of traditional export goods.[14] Diversifying exports through processes that add value to commodities and implementing new development strategies where innovation is the driver for growth are fundamental ingredients in the formula for success.

Integration policies may play a part in creating innovation clusters and fostering creativity through regional government procurement policies, for example.[15]

Trade agreements need to adapt to these new circumstances because negotiations are lagging behind the breakneck progress of technological change.[16] Trade in telerobotics- and telepresence-based services will require multilateral efforts to harmonize outdated regulations and standards.

The institutional and regulatory architecture of trade agreements is currently out of sync with innovation, and we need to address this. There is an important precedent for moving forward in this sense: trade agreements have helped close the technological divide between signatory countries through the knowledge spillovers that come with greater movement of goods, services, and people and more business-to-business technology transfers.[17]

Our mission is to reconfigure Latin America, improve its connection to the world and its access to new markets while increasing trade within the region and with the rest of the world. This new convergence will inevitably be hybrid in nature, part digital and part physical. The container trade and slow, complex borders of the past have opened the doors to instant trade, which is slowly gaining ground and pushing the old model aside before a death certificate has even been signed. E-books are a prime example of this and are gaining ever greater market shares even though print books remain on the market. Another example is online banking and new forms of payment which are blending with bank branches that provide increasingly personalized services.

Some 300 million people in the world live outside their country of birth. Cities are now centers of diversity, tolerance, and inclusion, and regionalism is the best means available to countries for optimizing their geography, scaling up their businesses, and forming partnerships with their neighbors. Khanna (2016) argues that we are headed towards a new form of connectography and hyperconnected cities. Latin America, with its small number of countries, shared history and culture, and lack of conflicts, has an advantage over other regions in this sense.[18] The speed at which postdigital changes are unfolding means that all countries are perpetual newbies. Regardless of the know-how they have accumulated or their past experience, all countries need to engage in lifelong learning.[19]

We are witnessing new synergies and associations that transcend the borders between companies through core businesses that now complement one another even though these connections were unthinkable until recently. Examples of this are the recent partnerships between Uber and the Brazilian company Embraer to manufacture flying taxis by 2020; between Google and Ford to produce driverless cars; or between Caterpillar and Airware to create mining drones.

The main advantage of the digital economy is the proliferation of services at a marginal cost of close to zero. Instagram outperforms Kodak because an infinite number of consumers can use the platform to share photos at the same time without incurring new costs (Brynjolfsson and McAfee, 2014).

The sharing economy reflects this hyperconnectedness. Another iconic example is Wikipedia, which 25 million users throughout the world have helped build. Access is worth almost as much as ownership, which is fading into the background as five new trends rise: dematerialization (making things with less materials), real-time demand (the supreme value of immediacy), decentralization (a single digital market), synergistic platforms (social networks connected to services), and access to the cloud (unlimited information) (Kelly, 2016).

People aren't the only things that are connected. Objects now communicate with one another through the Internet of Things, which Natarajan and Yentz (2016) argue reduces customer service response times by 30%, storage costs by 15%, and predicts future demand with an accuracy of 90%, among other commercial benefits. In 2016 alone, some 6.4 billion devices went online. By 2020, there will be over 20 billion. Global internet traffic is growing at a rate of 23% per year and by 2019 it will be 64 times greater than in 2005.

At the global level, 33% of food is wasted due to shortcomings and failures in logistics chains. Consequently, 96% of transportation and freight companies claim that the Internet of Things is the most important innovation of the last 10 years (Rhodes, 2016). MGI (2015) estimates the market for transportation applications of the Internet of Things will be worth US$560 billion in 2025.

New technologies often help close the infrastructure and equality gaps in many developing countries. More than 18 million people in Kenya use the M-PESA online payment system through their smartphones. The six trillion annual transactions made on the platform represent 25% of the country's GDP. This online payment system has brought 2% of the population out of extreme poverty and has been successful because it has brought down transaction costs and reduced the conflicts caused by lack of banking infrastructure and the poor state of roads in Kenya, which hampers the transportation of physical currency. Reducing market friction is the secret to success for any open innovation platform (Evans and Schmalensee, 2016).

In China, internet giant Alibaba made US$14 billion in sales in a single day. Around 68% of these transactions were made through mobile devices.[20] The digital market's prospects for growth go hand-in-hand with the need for better communication infrastructure to guarantee internet access for all. Facebook has been working on designing giant drones that could bring internet access to remote places (*The Economist*, 2017).

There will be winners and losers in this structural transformation. How should we address the social tensions that come with exponential change?

ARTIFICIAL INTELLIGENCE OR ARTIFICIAL ETHICS?

Artificial intelligence does not come as a package that includes artificial ethics. In the labor market, robot-

Promoting big data literacy among citizens is essential ics poses a moral and ethical dilemma regarding the loss of jobs that automation brings. However, the same thing has been happening since humans invented the wheel: the outcome of the use of each new technology ultimately depends on the prevailing ethical values of the time.

The online world is an excellent tool for promoting transparency. Public works are a clear example of an area that stands to benefit from this, as they need to combine smart physical connectivity with citizen accountability that builds people's confidence in governments and institutions. A model multilateral example of this is the Initiative for the Integration of Regional Infrastructure in South America (IIRSA) at the South American Infrastructure and Planning Council (COSIPLAN), a technical forum which INTAL/IDB functions as the technical secretariat for. Countries in the region agree on investment priorities for transportation, communications, and energy, and they make detailed information on each project available to their citizens. Big data can also help improve transparency in political campaign financing, another crucial area for integration, by making information open to citizens. Until politics detoxes from corruption, physical connectivity will never progress as quickly and intensely as Latin America needs, nor will the region be able to handle the regulatory challenges that these new circumstances have brought.

In sophisticated stock markets, robots can identify high-risk operations that have the potential to generate financial bubbles. When all the power is in the hands of greedy algorithms, the probabilities of financial crises increase, inevitably ending in costs being unfairly distributed within society.[21]

Answers to the moral dilemmas of automation are emerging in different areas. The Executive Office of the President of the United States (2016) has called for special attention to be paid to human rights violations using new autonomous weapons. It also recommends that content on safety and privacy policy ethics should be included in computer and data science curricula at schools and universities.[22]

The problem isn't artificial intelligence per se, but the fact that it exists alongside an artificial ethical code. If we do not manage to apply real ethics to artificial intelligence, the struggle to achieve equitable social inclusion will be very tough indeed.

A SOCIOTECHNOLOGICAL CONTRACT FOR LATIN AMERICA AND THE CARIBBEAN

Shifts in the labor market have given rise to the phenomena of hollowing out or polarization,[23] a process through which the numbers of high- and low-skilled jobs grow over time while medium-skill employment contracts due to the different impact of technological change. This points to two specific needs within education. First, the education system needs to provide young people with the tools they need to enter an increasingly sophisticated labor market. Second, it needs to function as a social leveler and prevent inequality and social fragmentation from becoming more intense.

Robert Aumann, one of the Nobel laureates who shares his ideas in this issue of *Integration & Trade*, insists that the three main priorities of public policy should be enough education, edu-

We need a new generation of conditional cash transfer programs

cation, and education. The best way to prepare for the future is with more and better education. But the challenges of technological change demand high-quality education that focuses on the skills that will be needed in the future. The key is building workers' technological capacities so that they can interact with machines and robots at work each day.

In Latin America, we need to promote big data literacy among citizens as this is an essential resource for improving productive efficiency. Without an education sector that contributes to developing creative talent using new technologies, this will be no easy task.

Massive online open courses (MOOCs) are one alternative for democratizing knowledge. We urgently need to set up legal frameworks that guarantee remote freelance workers their legal rights and anticipate the difficulties that new forms of employment imply for financing social security.[24]

The education revolution also needs to focus on soft skills, such as emotional intelligence, empathy, creativity, and not just solving problems but also posing new ones. These soft skills will be key for doctors, nurses, psychologists, social workers, and teachers as they are at the heart of tasks that cannot be robotized. We need to respond to the robotlution with a revolution in the public education system.

We are living through paradoxical times, when we seem unable to crush the hard core of inequality and guarantee all citizens a life of dignity, even though humanity has never produced so much wealth. This is why it is essential for us to rethink the classic welfare state in terms of these new parameters. Why can't innovation be introduced into the collective bargaining process as part of a sociotechnological contract that brings workers, business owners, and the state together in a long-term modernization plan? This is not a utopia. Multisector agreements have been implemented in Germany, Spain, the United Kingdom, and France, and have given rise to national industry 4.0 policies. It may sound paradoxical, but in the era of automation, we can't just wait for individual social interests functioning on autopilot to define the direction or priorities for social cohesion. What we need are clear rules of play.

In the last few years, the European Union has instigated two projects to put itself at the forefront of robotic agriculture: CROPS (Clever Robots for Crops) and Sweeper, which uses nanotechnology and new materials to automate primary production. Their aim is to introduce the first robotic harvester for greenhouses onto the market by 2020. Latin America can't be left behind by these advances in precision agriculture. The hybrid nature of this challenge blurs the boundaries between industry and agriculture and between goods and services.[25]

Technological change is a chance for us to use Latin America's voice to transform and continue promoting innovative convergence strategies among countries. An exclusive survey of millennials from Argentina that is part of the Integrology platform has found that over 70% of young people believe that robots will be able to do many of their jobs within 10 years. This is in line with the 32% of Latin Americans who look positively on the spread of robots to care for the elderly and the sick, among other potential applications (Beliz and Chelala, 2016). However, levels of technological awareness vary greatly by social class and level of education.

The economists Robert Solow and Dani Rodrik, two of the leading global experts in international economics and development, agree that the success or failure of globalization will depend on ensuring that digital dividends are distributed equitably.[26] As long as some citizens continue to live and work as we did in the 20th century and use technology from the 20th century (or the 19th century, in some regions), we will have not only a fragmented labor market but a divided society marked by escalating social conflict. The key lies in an egalitarian distribution of the benefits of technology and the opportunities that access to it bring.

While this educational transformation is emerging, we need to create support networks and social security coverage to help people transition effectively and sustainably to the new model so that those who are displaced by new forces of production do not become excluded by them. We need to reimagine social policies and implement creative new conditional cash transfer programs that include training in technological skills and a deep discussion of palliative measures such as universal basic income or taxation on robots, which are already being discussed by experts the world over.[27]

In the same spirit, we need to promote investment in research and development (R&D), not just from the public sector, but also through public–private schemes and other partnerships with academia. The region's current figures for this are alarming: the countries of Latin America and the Caribbean invest just 0.7% of their total GDP in R&D activities, while in North America and Western Europe the average rate is 2.5% and in the Asia-Pacific, 2.1%.[28] Reallocating resources to prioritize R&D would generate virtuous circles of knowledge and action.

The challenge that states are facing is how to mediate in the discussion of private property versus collective property (the sharing economy); tangible products versus intangible products (taxation in the digital world); human responsibility versus robot responsibility (autonomous vehicles); and data mining versus online privacy (cyber security). These are just some of the dilemmas that are demanding that we start thinking differently and adapt national and international standards to the speed and scale of technological disruption.

Training the government sector in analyzing real-time data will be essential. Automation will be key to increasing efficiency and improving access to public services in key social areas. A prime example of this is the potential of big data. In many global cities, intelligent information analysis is used to build public safety maps and to determine the strategic locations of police on the streets.[29] A similar case is the application of neuroscience to public policy-

The success of globalization will be defined
by whether digital dividends are distributed equitably

making: the data deluge raises our understanding of economic behavior and provides inputs for designing more dynamic public policies. Intelligent use of micro- and macrodata is what the new public administration is all about.

A complete recipe for buffering the impact of technological change would also include several other ingredients: diversifying exports, promoting small and medium-sized companies, the orange economy and creative industries, incentives for international cooperation, scaling up transfer policies, and improving environmental and food safety standards, to mention just a few.

There's no time to lose. The world is changing so fast that trades and professions that were useful yesterday become prehistoric overnight, like silent movies did when the first talkies were released.

It is our duty to be prepared and to create the right conditions for leading the technological transition towards smarter states and more solid, inclusive economies that create sustainable jobs. Behind each job loss is a person whose dignity is damaged. Nothing could be more important than rectifying this.

NOTES

[1] On the impact of innovation on the labor market and wage inequality see Acemoglu and Autor (2011) and Autor (2014).

[2] Mexico and Brazil top the robotization ranking in Latin America, with 14,000 and 10,000 robots, respectively (IFR, 2016).

[3] Oxford estimates that the average risk of job automation in the United States stands at around 47%, while Arntz, Gregory, and Zierahn (2016) put it at just 9% for the OECD. Agreement on a metric that would bring some clarity to these methodological variations would be a major contribution to the monitoring of automation-related risk to employment. See the articles by Frey, Aboal, and Coremberg and Nofal in this issue of *Integration & Trade.*

[4] See Curtis (2016). Another factor working in favor of the trend toward reshoring is the availability of a growing freelance work force ready to work remotely from anywhere on earth.

[5] See Ford (2015).

[6] See the article by Pacini and Sartorio in this issue of *Integration & Trade*.

[7] Tapscott and Tapscott (2016) analyze the impact that Bitcoin could have on global finance and production. Blockchain, the technology behind Bitcoin, may even create new disruptions in relatively recent success stories like Airbnb by enabling the creation of intermediary-free trade and commerce.

[8] See *Integration & Trade* 41, Eco-integration, which was inspired by the papal encyclical *Laudato Si'*.

[9] Peter Norvig, head of research at Google, argues that the greatest challenge that artificial intelligence poses is the risk of generating increased unemployment and greater inequality. He argues that in the past, technological disruption unfolded over generations rather than years, so we need to create social support networks to guarantee social stability (Brockman, 2015).

[10] See the article by Susskind in this issue of *Integration & Trade*.

[11] See Rhisiart, Miller, and Brooks (2015), Graetz and Michael (2015), UNCTAD (2016), Nübler (2016), and the article by Rhisiart in this issue of *Integration & Trade*.

[12] Kaplan (2015).

[13] Gans (2016) recalls that in 2000, Blockbuster had the chance to buy Netflix for just US$50 million. Netflix eventually caused the video rental chain to go bankrupt and now has a market value of around US$25 billion.

[14] See Giordano (2016).

[15] See INTAL (2017).

[16] INTrade (2017) provides a detailed look at what has been called the "spaghetti bowl" of globalization (the proliferation of international agreements), which in Latin America is made up of 158 agreements and negotiations with differing levels of compliance.

[17] See the article by Chelala and Martínez-Zarzoso in this issue of *Integration & Trade*.

[18] Kaplan (2016) dubs this advantage the "Pax Latina," although the region still needs to be strengthened through new trade agreements.

[19] In the same vein, Ito and Howe (2016) put forward a series of principles for facing up to the speed of these changes (including resilience, disobedience, diversity, and continual practice).

[20] This issue is examined in more detail in Schwab (2015), who discusses the invention of November 11 as "singles' day."

[21] On May 6, 2010, at 2:45 PM EDT, the United States stock markets experienced a "flash crash": the stock market plummeted by about 1000 points following algorithmic trading by a robot stock trader which sold 75,000 futures contracts valued at approximately US$4.1 billion. *Natural Scientific Report* researcher Neil Johnson, who published a study on the event, described the financial world as having been transformed into a "cyber jungle."

[22] A similar initiative is the Partnership on Artificial Intelligence to Benefit People and Society, led by some of the largest tech companies on the planet (Amazon, DeepMind/Google, Facebook, IBM, and Microsoft). https://www.partnershiponai.org/.

[23] See McIntosh (2013).

[24] See the interview with Alan Krueger in this issue of *Integration & Trade*.

[25] Another potential threat is the growing danger that

synthetic meat poses to Latin American exports of traditional meat, which was analyzed at a seminar organized by INTAL (see www.iadb.org/intal).

[26] See the interview with Robert Solow in *Integration & Trade* 39 and the interview with Dani Rodrik in this issue.

[27] See the article by Cristina Calvo in this issue of *Integration & Trade*.

[28] See INTAL (2016), which examines the role of investment in R&D in Asian development in recent decades.

[29] A case study in this issue focuses on Chicago, which has pioneered this activity.

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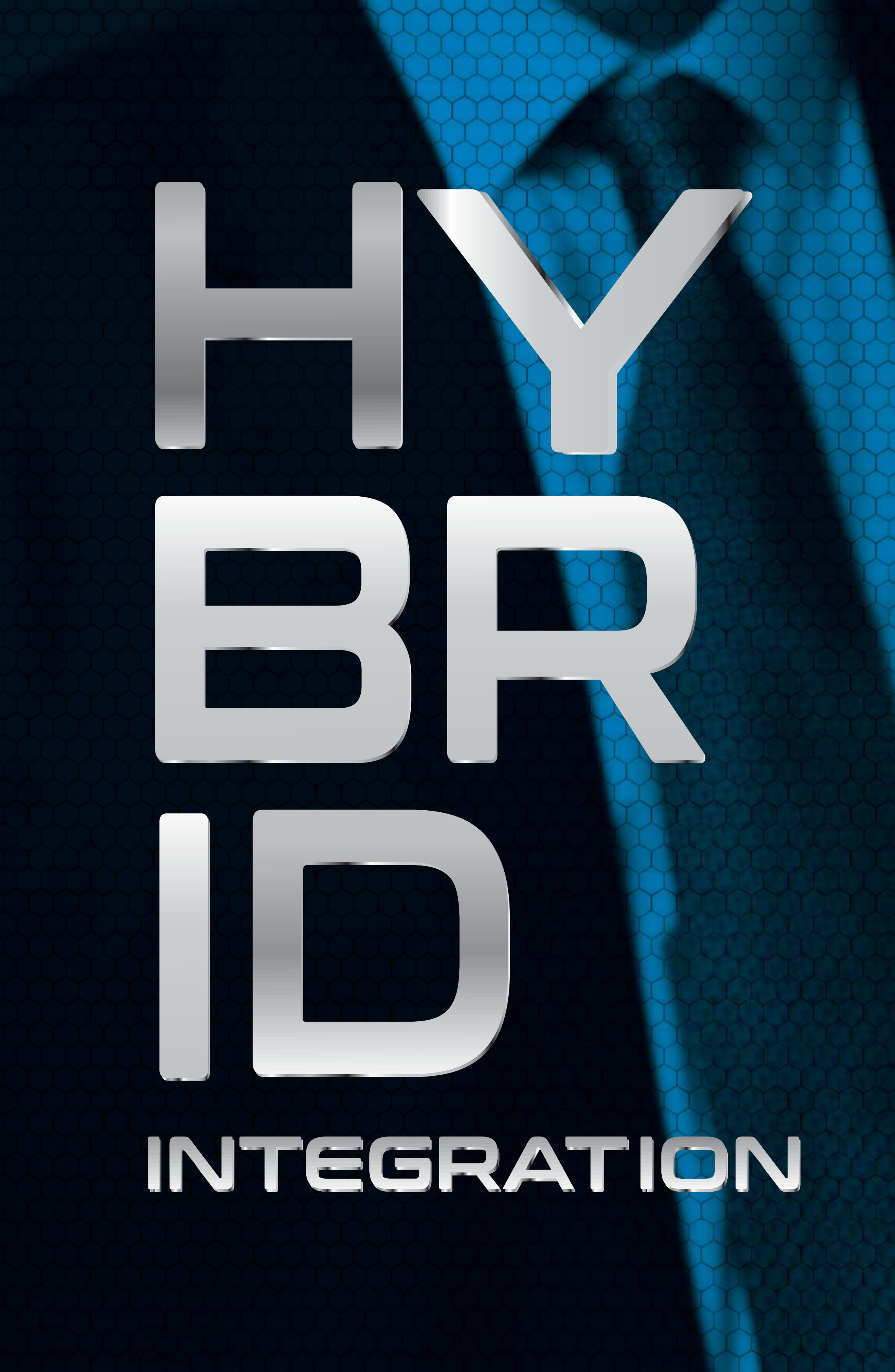
New production techniques and the digital economy are breaking down the barriers between goods and services, altering trade mechanisms, and transforming labor habits.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INTEGRATION

ANALYSIS

Workers against robots?

How to win the most important battle of the 21st century

Carl Benedikt Frey
Oxford Martin School

The human spirit must prevail over technology.

Albert Einstein

CARL FREY, ONE OF THE MOST CITED AUTHORS ON THE ISSUE OF AUTOMATION, CLAIMS THAT THE PHENOMENON IS OFTEN ASSOCIATED WITH PAINFUL TRANSITIONS FROM NEW TO OLD JOBS. THOUGH SUCH TRANSITIONS CONSTITUTE A PREREQUISITE FOR LONG-RUN GROWTH, THERE IS NO GUARANTEE FOR SHARED PROSPERITY. THIS NO DOUBT SPELLS GOOD NEWS FOR GROWTH, BUT FOR WORKERS, THE KEY QUESTION REVOLVES AROUND THE TYPES OF JOBS THEY WILL MOVE TO.

The benefits of the computer revolution have not been widely shared. Since the 1980s, when the widespread use of computers began, median wages have been stagnant, the labor share of income has fallen, and labor force participation has dropped dramatically within certain skill groups. Part of the explanation is that automation has led to the demise of many middle-income jobs, including those of machine operators, billing clerks, paralegals, and insurance claim appraisers. As a result, labor markets across advanced economies have become increasingly polarized as middle-income jobs have disappeared due to automation.

More recently, polarization has become equally pronounced in parts of the developing world as well. Looking forward, the pace of automation does not seem to be slowing down. Research suggests that 47% of US jobs, 57% of jobs across the OECD, and 77% of jobs in China are now exposed to automation because of recent advances in machine learning and mobile robotics (Frey and Osborne, 2013; World Bank, 2016).

THE GLOBAL DOWNFALL OF MANUFACTURING EMPLOYMENT

The prime inventions of the past century—including electrification, the internal combustion engine, and the semiconductor—created entirely new occupations and industries. Indeed, the wealth of nations has accumulated by shifting the bulk of the workforce from low- to high-productivity jobs. Over the course of the 20th century, industrialization has constituted the path to prosperity, allowing countries to shift workers from agriculture to relatively well-paid, high-productivity manufacturing jobs.

Importantly, nearly all of those jobs emerged in highly skilled tradable sectors, most prominently, finance, computer design, and engineering. Most job loss, in contrast, took place in the electronics industry, agriculture, cut-and-sew apparel manufacturing, fabric mill, aerospace, paper, chemicals, and the auto industry. While such job loss can be attributed to shifts in production to low-cost destinations, the fact that manufacturing employment in China and elsewhere has already peaked at levels much lower than those experienced by today's industrial nations suggests that these jobs are subject to automation and that they are not coming back.

Economic progress means shifting workers into new occupations and industries; not old ones. A concern is therefore that today's new technology sectors have not given rise the same employment opportunities for less educated workers as the industries that preceded them did.

Estimates by Berger and Frey (2016a), for example, show that less than 0.5% of the US workforce changed to technology jobs that were created throughout the 2000s; for the 1990s, the equivalent figure was 4.4%. Yet despite computer technology failing to create the same job opportunities as technologies of the past, most workers, at first glance, seem able to find new jobs. The reason is simple: while the tradable sector has not created many new jobs directly, it has created significant demand for local services, and thus nontradable jobs.

57%

OF JOBS IN OECD COUNTRIES RUN THE RISK OF BEING AUTOMATED

In the words of Glaeser (2012): "Today's innovation-rich sectors have not provided the same opportunities for less well-educated Americans than the smokestack industries that preceded them. But it may not matter if less-skilled workers are directly employed by computer companies and biotechnology firms, or if they are employed indirectly by the employees of those firms, who demand plenty of the services provided by the less-skilled. Local nontraded service providers may not have experienced the same technological miracles as software production, but that is where most Americans work and their fates are tied to their ongoing ability to sell their time to those workers who sell exportable goods and services."

Indeed, as shown by Moretti (2010), every new technology job will create approximately 4.9 additional local service jobs. Technology jobs, in other words, still play a critical role in creating demand for local service jobs. A recent study by Berger, Chen, and Frey (2016) has shown that the multiplier associated with skilled manufacturing jobs is even greater in the developing world; approximately 6 to 9 times larger than the skilled multiplier documented for the United States. By shifting towards more skilled production, developing countries would equally boost domestic demand, creating plenty of local service jobs along the way.

A GROWING CONCENTRATION

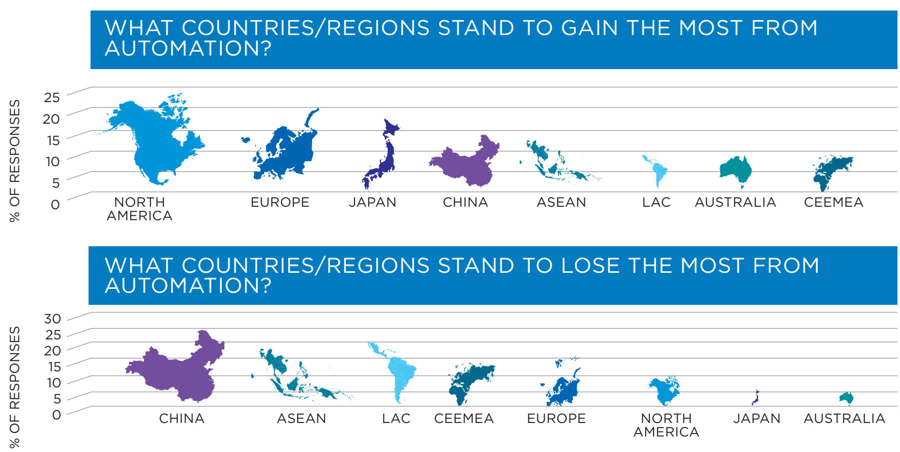
This dynamic means that economic activity is becoming increasingly concentrated. The common belief that the digital revolution would make geography irrelevant by allowing people to work from remote locations seems disproved today. Regional income disparities within advanced economies have increased rather than improved over recent years. In the United States, San Francisco has an average per capita income of US$38,000, while average incomes in Laredo, Texas, are below US$11,000; in Europe, the 2013 GDP per capita in Extremadura in Spain was 16,900 compared to 31,600 in Madrid. One of the reasons for such income disparities is that new jobs cluster.

Especially since the computer revolution of the 1980s, new jobs have overwhelmingly emerged in cities with an abundance of skilled workers (Berger and Frey, 2016b). The typical example, the Bay Area, is home to many of the companies leading the digital revolution, including Google, Instagram, Dropbox, Uber, Facebook, eBay, and LinkedIn. As technology jobs tend to cluster, the demand for local services is becoming increasingly concentrated as well: low-skilled workers will have to move to places where new technology jobs are created.

Meanwhile, old jobs are being automated away to locations different from the ones where new jobs are emerging. One reason why low-skilled workers are more likely to become unemployed is that they tend to be less mobile across locations; a reason that is in part financial. Relocation is like any other investment, in that money is spent upfront in order to obtain a better-paid job elsewhere.

Paying for the immediate expense of moving in return for eventually higher earnings in the future is not an option for everyone. Because many

FIGURE 1
AUTOMATION: WINNERS AND LOSERS



Source: Data based on a survey published in Frey and Osborne (2016).

low-skilled workers lack the financial means for such an investment, the introduction of relocation or mobility vouchers would service an increase in mobility and employment (Moretti, 2012). Vouchers and similar policies are even likely to pay for themselves: a worker moving from Detroit to San Francisco to take a better job will need fewer transfer payments and pay more taxes. Because relocation generates positive returns to both worker and society, such policies are highly recommendable.

4.9

ADDITIONAL JOBS ARE CREATED FOR EACH NEW TECHNOLOGY JOB

TOWARDS UNIVERSAL ACCESS TO QUALITY EDUCATION

Beyond managing the relocation of the workforce, education is critical, not least because new jobs tend to cluster in places with a highly skilled workforce. Moreover, education is what allows workers to successfully shift into new jobs. Over recent decades, skilled workers in automatable activities were on average more successful with their transition into better-paid jobs, while low-skilled workers, who have seen their jobs being automated away, have typically taken on low-income jobs or have dropped out of the labor force.

Nonetheless, the quality of educational institutions in general and schools, in particular, varies considerably across locations; students are therefore often subject to the curse of geography and might suffer from geographical disadvantages even from an educational point of view. Ensuring that there is still opportunity in locations that have experienced economic decline requires making quality education available also in deprived regions; while places that have invested in physical capital have experienced continued decline, the places that have succeeded are the ones that have invested in human capital.

Education can be upgraded and better distributed using digital technology. So-called MOOCs (Massive Open Online Courses), when properly designed and thoughtfully distributed, can improve learning in both schools and higher education institutions which can make geography less important as students will access the best content and teachers regardless of their location. The only obstacle between all children having access to some of the best classes and methods of learning in the world is the ability and willingness of governments to promote online learning and to provide the respective technological infrastructure to all inhabitants.

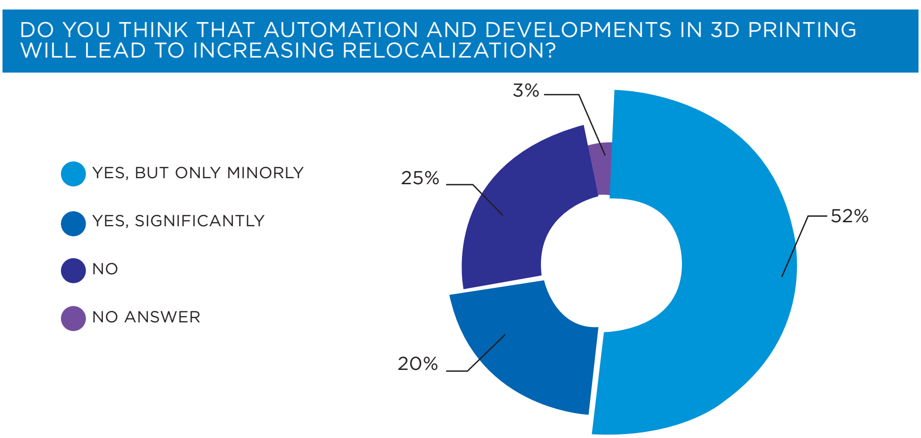
Although improving the quality of children's education and access to it are important; lifelong learning is of growing significance for workers seeing their skills made redundant by automation later in their careers. To maintain a competitive workforce, and to give workers the skills to remain in employment throughout their careers, governments need to offer training opportunities throughout people's working lives. Again, MOOCs offer a potential solution, making time a redundant factor in contemporary education. Instead of participating in academic programs spanning over a specified period, digital technologies allow students to study at their own pace.

Breaking down the learning process, leaving students with a menu of skills they can choose from, without the need to necessarily complete a standardized academic program but an option to continue, MOOCs can provide modularized approaches to education that suit even employers looking to retrain their workforce. Because many skills remain occupation- and industry-specific, governments should include industry and professional bodies in the discussion process to develop modular programs that are recommendable for specific career paths.

The advantages of online learning in business should not be reduced to a method of cost reduction but as a tool that improves access to education and the quality of the learning process as well. More big data on students' learning behavior will help the designers of content for educational programs to evaluate their students' performance and progress and identify ways to improve their learning efforts. In the context of higher education, a recent study comparing an MIT MOOC to its equivalent on-campus course found that the MOOC students performed better when taking the online course (Colvin et al., 2014).

However, students will still need human tutors that encourage them to learn and take an active part in guiding them throughout the learning process and of course will need to help students develop their social interactions during such learning. Especially

FIGURE 2
EXPECTATIONS AROUND THE IMPACT OF AUTOMATION AND DIGITAL MANUFACTURING



Source: Data based on a survey published in Frey and Osborne (2016).

in higher education, there are limits to what online platforms can achieve: MOOC students underperform relative to on-campus students in group work, which underlines that interactive face-to-face learning methods are still critical to fostering a certain set soft of skills. Physical interactions between students are likely to become even more important as social and creative skills are the ones that remain most difficult to automate and could become increasingly valuable in the labor market.

Online education should therefore not substitute for the work of teachers but will change the skills of teachers in the near future. Online learning should be accompanied by teachers becoming tutors, working interactively with students, and help guide their learning using online tools, facilitate interactions between students in tutorial-style teaching, and challenge their curiosity to explore the world beyond the boundaries of their respective learning program.

PREMATURE DEINDUSTRIALIZATION

A key concern is that industrialization will not constitute the engine of shared prosperity going forward. The simple reason for this is that manufacturing is becoming more automated across the board. Peak manufacturing employment has experienced a secular decline over recent decades: whereas manufacturing employment in the United States peaked at above 30% of total employment in the 1950s, manufacturing employment in countries like China, Brazil, and India has already peaked at well below 20% (Rodrik, 2015). Such "premature deindustrialization," as it has been called, is the result of automation in the tradable sector. Even in China and Thailand, automation largely provides a cheap substitute for workers (Citi, 2016). In the light of these trends, the recent political drive in the United States, and elsewhere, to bring back manufacturing jobs seems doomed to fail. Indeed, in advanced economies, the direct impact of manufacturing on employment has been negligible for quite some time. Estimates by Spence and Hlatshwayo (2012) show that nontradable sectors, producing goods and services that are consumed locally, can account for as much as 98% of total US employment growth between 1990 and 2008. Around 40% of this growth, in turn, came from government and healthcare services, which are notably not primarily driven by market forces, while the retail, construction, food and accommodation industries also contributed significantly.

At the same time, the tradable sector, which accounted for more than 34 million jobs in 1990 and produces goods and services that can be exported, such as manufactured products and professional services, grew by a negligible 0.6 million jobs.

NO-ONE IS IMMUNE

As old jobs are being automated away, a key priority for governments is to ease the transition of workers into new types of jobs. No country is immune to automation. The challenges are similar in advanced and developing economies alike. The share of manufacturing employment will continue to decline on a global scale, requiring even developing countries to shift towards more skilled production that remains outside the domains of computer-controlled technologies. For countries like China, seeking to move towards more consumption-led growth, such a growth strategy provides the best way forward. Skilled workers exhibit higher incomes and create additional demand for local services, and thus local service jobs. As a result, however, economic activity is becoming increasingly concentrated.

Policies to help workers relocate to expanding cities and regions are required, especially to help low-skilled workers move, which tend to be less mobile across locations. Moreover, because new jobs tend to cluster in places with a greater abundance of skilled workers, policies that facilitate investment in education and training are essential for places to remain competitive in job creation. Digital educational platforms provide a promising way of providing access to cost-effective education for workers regardless of their location.

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"We must not allow the creation of a bifurcated labor market"
Dani Rodrik
Harvard University
ECONOMICS RULES
DANI RODRIK

INTERVIEW

One of the most influential economists in the world, Dani Rodrik is also an expert on Latin America. The book *Integrating the Americas*, which he edited with Antoni Estevadeordal, Alan Taylor, and Andrés Velasco, is a classic analysis of integration processes in the region. In this interview, the Harvard professor describes the ideal institutional framework for encouraging innovation and how new technologies will impact globalization and employment.

Can you describe your proposal for an "innovation state" to replace the welfare state?

The welfare state was largely about safety nets, social insurance, and redistribution. It focused on taking the edge off capitalism and redistributing its proceeds more evenly. An innovation state would focus on making the nation as a whole, including workers, direct participants in the process of technological innovation that is unfolding at an ever-greater speed. That in turn means two things. First, we must begin thinking of the state, which is the agent of ordinary people, as the largest source of venture capital. The government and public institutions enable the ecosystem that fuels innovation, either directly by subsidizing it or by providing the public inputs—education, infrastructure, legal system—that facilitates it. So it is not a stretch that the government should be seen as an equity participant in the robots and new technologies that come out. Second, we need to figure out how to disseminate more broadly the skills, training, and capacities that will allow more workers to take advantage of the new technologies. We must not allow the creation of a bifurcated labor market, in other words.

> PERU'S *MESAS EJECUTIVAS* ARE AN EXCELLENT EXAMPLE OF DIALOGUE BETWEEN THE PUBLIC AND PRIVATE SECTOR

In previous industrial revolutions, many jobs were lost, especially low-skilled jobs. Will it be different this time round?

We do not know yet. There is always a lag between the introduction of new technologies and the emergence of benefits in terms of widespread wage gains. We might be going through a similar cycle. But, nevertheless, we must think of the requisite institutional transformations, and not just sit idly by. Each industrial revolution has brought revolutions in the form that capitalism is organized. It will be similar this time.

Do you foresee radical changes in global value chains due to new technologies such as artificial intelligence and 3D printing?

We clearly see comparative advantage in manufacturing moving away from low-income, low-wage countries.

DANI RODRIK WAS BORN IN TURKEY IN 1957 BUT HE HAS SPENT ALMOST HIS ENTIRE LIFE IN THE UNITED STATES, WHERE HE EARNED HIS PHD AT PRINCETON UNIVERSITY. HE IS CURRENTLY THE FORD FOUNDATION PROFESSOR OF INTERNATIONAL POLITICAL ECONOMY AT HARVARD KENNEDY SCHOOL. HIS MAIN WORKS INCLUDE:
THE GLOBALIZATION PARADOX. NORTON & CO. 2011.
ONE ECONOMICS, MANY RECIPES. PRINCETON UNIVERSITY PRESS. 2007.
THE GLOBAL GOVERNANCE OF TRADE AS IF DEVELOPMENT REALLY MATTERED. UNDP. 2001.
THE NEW GLOBAL ECONOMY AND DEVELOPING COUNTRIES: MAKING OPENNESS WORK. JOHNS HOPKINS UNIVERSITY PRESS. 1999.
HAS GLOBALIZATION GONE TOO FAR? INSTITUTE FOR INTERNATIONAL ECONOMICS. 1997.

Once you can make shoes cheaply with 3D printing, you do not need to outsource to low-cost locations. So value chains are being reshored, and low and middle income countries are experiencing what I have called premature deindustrialization. As a consequence, I see very little chance that other countries will be able to replicate the export-oriented industrialization miracles of East and Southeast Asian countries. Achieving rapid growth is becoming much harder.

IT WILL BE INCREASINGLY DIFFICULT TO REPRODUCE THE ASIAN EXPORT GROWTH MODEL

How can we promote innovation in general and in Latin American countries in particular?

Much of Latin America is plagued by the paradox that the most modern parts of the economy are doing very well, in that they are as sophisticated as any in the world. But economywide productivity is sluggish. Bridging this dualism is the essential challenge.

Education and improved institutions are the long-termsolution. In the short to medium-term,we need governments to be nimble and experimental, helping modern-sector firms overcome obstacles that prevent them from growing and absorbing greater amounts of labor from the lagging parts of the economy. These obstacles are highly specific to each type of activity and cannot be removed through generic "structural reforms." That is why we need a more hands-on government.

Would it be possible to build a new Silicon Valley in Latin America?

There are plenty of centers of excellence in Latin America. As I explained the challenge is to connect them better with the rest of the economy. The key

THE GOVERNMENT SHOULD BE SEEN AS AN EQUITY PARTICIPANT IN ROBOT DEVELOPMENT

is to bridge the gap between the frontier activities in the economy—whether in manufacturing, services, or agriculture—and the lagging activities.

What public policies have been implemented around the world that have had good results?

Actually, some of the best experiments with the kind of nimble, hands-on industrial policy I have in mind are taking place currently in Latin America. I would point for example to the Mesas Ejecutivas in Peru as being very good examples of how you set up a public-private dialog and address binding constraints.

What are the new dilemmas that technological changes are posing to globalization?

While we fail to undertake the institutional innovations required to spread the benefits of technology, I am afraid the risks of backlash—against globalization, against immigrants, and against liberalism—will continue to increase.

Is global governance prepared to deal with the consequences of a technological revolution?

I think we exaggerate the need for and importance of global governance. Most of our problems arise from failures of domestic governance, and these cannot be fixed by trade agreements or multilateral arrangements. In fact, the pursuit of global governance has diverted our policy and financial elites from working out the domestic bargains required to sustain open, healthy economies. It is both a symptom and a cause of the populist backlash and the growing divide between these elites and ordinary voters.

IN RODRIK'S OWN WORDS

Dani Rodrik's blog, *Unconventional Thoughts on Economic Development and Globalization*, is extremely popular among economists. Through it, the Harvard professor shares his ideas on the dynamics of the international economic situation in plain language.

- The fundamental political problem with trade is not there are winners and losers—the domestic market generates much greater job churn and dislocation than trade does. It is that it generates unfair redistribution, or at least redistribution that can be legitimately perceived as unfair.
- A usual argument against the use of capital controls as a prudential measure is that it is always better to tackle problems at their source rather than trying to deal with symptoms.
- The problem with indirect remedies is that they create problems themselves.
- One of my favorite aphorisms is "the world is second best, at best." It tells us that first-best logic can be misleading in the real world.
- Recent growth accelerations were based on either rapid within-sector labor productivity growth (Latin America) or growth-increasing structural change (Africa), but rarely both at the same time.

GENERATION Y

THROUGH A QUALI-QUANTITATIVE SURVEY, INTAL SOUGHT TO EXPLORE HOW ARGENTINIAN MILLENNIALS VIEW EXPONENTIAL CHANGE AND ITS EFFECTS ON WORK, EDUCATION, AND TRADE INTEGRATION. THE SURVEY ALSO AIMED TO UNDERSTAND HOW THESE TRENDS AFFECT THE WAY THEY PLAN THEIR EDUCATIONS, CAREERS, AND PERSONAL LIVES.

70% BELIEVE THAT ROBOTS WILL COME TO PERFORM MOST WORK WITHIN THE NEXT TEN YEARS BUT ONLY 25% THINK THAT THEIR OWN JOB WILL BE AUTOMATED

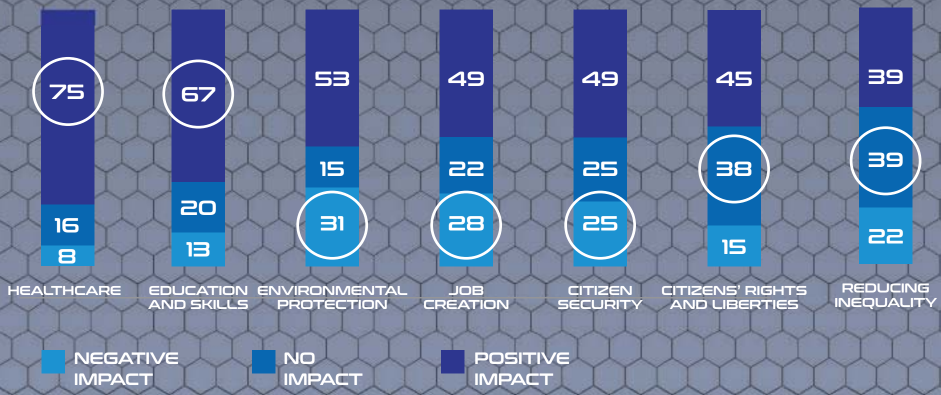
84% HAVE SOME TECHNOLOGICAL SKILLS, BUT 50% BELIEVE THAT A FORMAL EDUCATION IS MORE IMPORTANT FOR GETTING A JOB

58% WOULD PREFER A NONTECHNOLOGICAL JOB AND ONLY 13.6% CONTINUALLY USE AND APPLY TECHNOLOGY IN THEIR CURRENT JOBS

93% OWN A CELLPHONE WITH INTERNET ACCESS AND SPEND FOUR HOURS EACH DAY TEXTING

VIEWS ON INNOVATION

Over the next 15 years, how will science and technology impact the following issues?



SOURCE: COMPILED IN-HOUSE BASED ON THE INTAL VOICES SURVEY, 2017.

ANALYSIS

I wasn't trying to predict the future,
I was trying to prevent it.

Ray Bradbury

Diego Aboal and
Gonzalo Zunino
Center for Economic Research
(CINVE)

Innovation and skills in Latin America

INNOVATION IS KEY TO PRODUCTIVITY GROWTH IN COUNTRIES DUE TO ITS POSITIVE EFFECTS ON UNEMPLOYMENT. HOWEVER, THERE IS FAIRLY CLEAR EVIDENCE THAT INNOVATION IS SKILLS-BIASED, IN OTHER WORDS, IT FAVORS DEMAND FOR MORE SKILLED LABOR, WHICH POSES A SIGNIFICANT CHALLENGE IN TERMS OF SOCIAL PROTECTION.

Innovation, or the introduction of new products, processes, and organizational or marketing approaches, is increasingly understood as being essential to countries' growth. Innovation has been a major factor in the growth of several OECD countries (OECD, 2010). The growth in multifactor productivity that is linked to innovation explains much of the total productivity growth in these countries. Differences in multifactor productivity also explain much of the disparity between advanced economies and emerging economies. This indicates that innovation is key to reducing the productivity gap between these two types of economies.

Based on such evidence, Latin American countries are increasingly seeing innovation as a way to increase competitiveness, diversify their economies, and move toward activities with greater value added. This has led to the creation of support policies for innovation throughout Latin America and the Caribbean. However, one aspect that should not be overlooked is that innovation can have major impacts on employment. Given this, understanding the link between innovation and employment in Latin America may help those designing innovation policies to minimize the negative impacts that innovation may have on employment and maximize its positive impacts.

How innovation affects employment depends on multiple factors that operate in different directions. First, it depends on the type of innovation in question. Product innovations tend to have a positive effect on employment, while process innovations generally have no effect or a negative one. The effects also depend on the sector in which the innovations are introduced. Knowledge-intensive sectors are continually innovating and tend to employ a type of human capital that is more flexible to these changes. Effects on employment also depend on the type of technology that is introduced, as these define the productivity improvements that firms may have and thus their capacity to capture greater demand via price reductions or higher-quality products.

A range of indirect effects may arise at both the sector-specific level and in the economy as a whole. For example, jobs could be displaced from firms with low levels of innovation intensity to highly innovative firms. Companies that do not innovate may die off while new companies and jobs may be created as a consequence of innovative ideas. Finally, innovation may lead to global improvements in the competitiveness of the economy through, for instance, more efficient and better-quality suppliers, which could lead to greater competitiveness in foreign markets and higher employment levels.

However, beyond the global effects that innovation and technical change have on unemployment, several studies have drawn attention to the profound transformations that these processes may generate within the labor market and employment as we know them today. The recent study by Frey and Osborne (2013) and the earlier publications by Autor, Levy, and Murnane (2003) and Acemoglu and Autor (2011) are the touchstones in a series of studies in recent years that have drawn the public's attention to how technological change, particularly in the field of robotics, may replace many existing jobs, which would cause a phenomenon that is commonly referred to as "technological unemployment."

To a greater or lesser extent, these studies reveal the implications that technological progress may have for the future of our societies. So, for example, depending on whether machines are able to replace only low-skilled labor, skilled labor, or all labor, the distributive consequences will be different, as will the social transformations that will need to accompany these changes.

Given the above points, this article begins by reviewing the main results found in the economic literature on the relationship between innovation, technological change, and employment in order to better understand the connection between these processes and the labor market. It also examines how sensitive the labor markets of Argentina and Uruguay may be to technological progress, focusing on robotization and the automation of current jobs. This exercise seeks to quantify the scale of the transformations that these labor markets may undergo in the near future and in coming decades, while also identifying the groups that are most vulnerable to these transformations. This article concludes with some reflections on the economic policy implications of this analysis.

COMPENSATION AND DISPLACEMENT

In general, we would expect innovation to have two main effects of unemployment at the firm level. The first is a loss of jobs due to a reduction in the labor requirement per product unit. The second is a positive compensation effect brought about by the growth in sales and production. This second effect is linked to both the reduction in marginal costs (lower prices generate greater demand) and the creation of new products that require additional labor. These effects on employment may be more or less significant depending on the structure of the market (for both goods and

TABLE 1
THE EFFECT OF INNOVATION ON EMPLOYMENT

TYPES OF INNOVATION	DISPLACEMENT EFFECT	COMPENSATION EFFECT	FORCES AT WORK
PROCESS INNOVATION	Productivity effect (-): less labor for a given output	Price effect (+): reduction in costs, repercussions on price, increased demand.	Agent behavior.
PRODUCT INNOVATION	Differences in productivity between old and new products (+ or –). Effects of demand on existing products (+ or –): market cannibalization?	Effect of increased demand (+): larger market.	Competition between firms.

Source: Adapted from Harrison et al. (2008).

production factors) and the sectors in which innovation takes place.

The behavior of executives and workers within companies can also exacerbate or reduce the effect of displacement and strengthen or weaken the compensatory effects. For example, a company's market strength and workers' wage bargaining power could limit innovation-related cost savings from being transferred to prices and thus may weaken the positive effects of innovation on employment.

Other factors include partial effects within each sector (reallocation of production and employment between firms that innovate more and those that do so less) and general equilibrium effects when the interaction between different markets is taken into account.

Finally, it is important to point out that innovation affects not only the number of jobs that have been created but also the quality of these. Innovation may be associated with lower growth in employment among less-skilled workers, while also increasing the demand for skilled labor. Depending on the skills bias of the innovation in question, it may impact skilled and unskilled workers differently (see table 1).

EMPLOYMENT IN MANUFACTURING

In this section, we will look at the results available for the manufacturing industry in Latin America. These results come from a series of studies carried out by the IDB (Aboal et al., 2011; Alvarez et al., 2011; and De Elejalde, Giuliodori, and Stucchi, 2011) which were systematized and expanded in Crespi and Tacsir (2012). These studies estimate the impact of product and process innovations on employment.

Table 2 shows the results for global employment. When countries' entire manufacturing sectors are taken into account, the results show that product innovation has a significant positive effect on employment for all the coun-

9%

THE RISK OF AUTOMATION IN THE UNITED STATES, ACCORDING TO THE OECD

tries analyzed. In contrast, process innovation generally had no significant effect on employment (Argentina, Chile) or had a negative effect (Uruguay). Only in Costa Rica did it have a positive impact. This last result could be due to the fact that these process innovations may not have generated significant productivity gains and thus did not displace jobs. It may also be the case that even when there have been significant productivity gains and there has been a displacement effect on the labor force, this may have been compensated for by market expansion (through price reductions, for example), which would have led to a net positive effect.

The evidence presented by Harrison et al. (2008) for some European countries (France, Germany, Spain, and the United Kingdom) is similar to these findings for Latin America. The results for small firms (those with less than 50 employees) and for high- and low-tech firms are similar to the findings for the entire manufacturing sector. Perhaps the most noteworthy result is that the displacement effect of process innovation in Uruguay is stronger in larger firms and in the high-tech sector.

TABLE 2
INNOVATION AND EMPLOYMENT IN MANUFACTURING FIRMS IN LATIN AMERICA

DEPENDENT VARIABLE: ADJUSTED EMPLOYMENT

REGRESSION\COUNTRY	ARGENTINA	CHILE	COSTA RICA	URUGUAY
All manufacturing firms				
Process innovation only	1.398	0.333	18.413*	-2.716**
Growth in sales due to new products	1.170***	1.751***	1.015***	0.961***
Small manufacturing firms				
Process innovation only	-2.542	-3.38	15.415	-2.595
Growth in sales due to new products	1.140***	2.141*	1.051***	0.998***
High technology vs. low technology				
Low technology				
Process innovation only	0.849	-0.517	ND	-2.524
Growth in sales due to new products	1.105***	1,403*	ND	0.956***
High technology				
Process innovation only	-1.45	-0.076	ND	-2.897**
Growth in sales due to new products	0.910***	1,695**	ND	0.958***

Notes: the employment variable is adjusted for sales of old products. Estimation by instrumental variables. *, **, ***: significant at 10%, 5%, and 1%, respectively. Small firms are those with less than 50 employees. High-tech firms are those where the ratio of innovation expenditure to sales is higher than the median. NA = not available. Process-only innovation is a dummy variable that indicates the introduction of process-only or organizational innovation by firms.
Source: Crespi and Tacsir (2012).

The results that are summarized in table 3 point to interesting patterns regarding the impact of innovation on the make-up of labor-force skill. First, product innovation is always significant. The coefficient for the growth in sales of new products (the product innovation indicator) is systematically around 20% higher for skilled labor than unskilled labor in Argentina and Uruguay. In other words, product innovation generates greater demand for skilled labor than for unskilled labor. Furthermore, the coefficients for the product innovation variable are fairly similar to those of Costa Rica.

Process innovation variables are not statistically significant for Argentina, are negatively significant for unskilled labor for Uruguay, and are, surprisingly, positive and significant for Costa Rica.

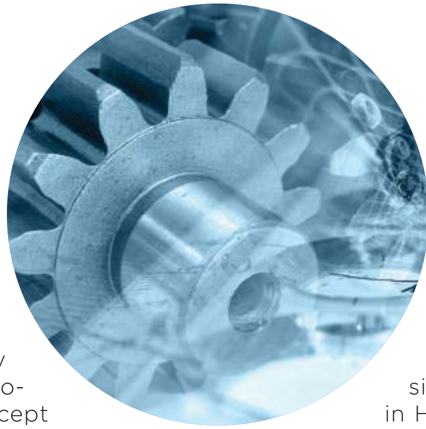
The results for small companies are very similar to the results for the entire sample.

Estimations for the low-tech sector did not show any evidence of an innovation skills bias. Uruguay was the only country where there was a very high coefficient for unskilled labor in comparison with skilled labor. In the high-tech sample from Uruguay, there is evidence of a skills bias due

TABLE 3
INNOVATION AND EMPLOYMENT QUALITY IN MANUFACTURING FIRMS IN LATIN AMERICA

REGRESSION/COUNTRY	ARGENTINA		COSTA RICA		URUGUAY	
	SKILLED	UNSKILLED	SKILLED	UNSKILLED	SKILLED	UNSKILLED
All manufacturing firms						
Process innovation only	3.048	2.488	10.465	26.260**	2.379	-3.373*
Growth in sales due to new products	1.308***	1.126***	1.010***	1.020***	1.087***	0.929***
Small manufacturing firms						
Process innovation only	-3.696	0.218	4.371	17.478	5.116	-3.281
Growth in sales due to new products	1.346***	1.075***	1.012***	1.068***	0.970***	0.916***
High technology vs. low technology						
Low technology						
Process innovation only	-0.042	1.585	ND	ND	0.114	-1.587
Growth in sales due to new products	0.973***	0.968***	ND	ND	0.817***	0.894***
High technology						
Process innovation only	-1.028	-0.585	ND	ND	-0.134	-5.781***
Growth in sales due to new products	0.952***	0.938***	ND	ND	0.873***	0.835***

Notes: the employment variable is adjusted for sales of old products. Estimation by instrumental variables. *, **, ***: significant at 10%, 5%, and 1%, respectively. Small firms are those with less than 50 employees. High-tech firms are those where the ratio of innovation expenditure to sales is higher than the median. NA = not available. Process-only innovation is a dummy variable that indicates the introduction of process-only or organizational innovation by firms.
Source: Crespi and Tacsir (2012).



to the introduction of new products. Finally, there is no evidence of skills biases being caused by the introduction of process innovations, except the negative bias toward unskilled jobs in the case of high-tech companies in Uruguay.

EMPLOYMENT IN THE SERVICE SECTOR

Empirical information on the relationship between innovation and employment in the service sector is scant and is mainly limited to European countries. In this section, we will summarize the results of estimations for Uruguay and will compare them with three recent studies that reported results for European countries (Leitner, Poschl, and Stehrer, 2011; Dachs and Peters, 2013 and Harrison et al., 2008).

Perhaps surprisingly, table 4 shows that the results for Uruguay are similar to those for many European countries. The coefficients of the variable for growth in sales due to new services (an approximate variable that is a proxy for product innovation) is positive for Uruguay and is in the same range of values as most European countries or groups of these (the only exception are the southern European countries discussed in Leitner et al., 2011). As is shown in table 4, the effect of product innovation on employment is positive and significant in all cases. The evidence for process innovation presented in table 4 is mixed. In the case of Uruguay, the process innovation variable tends to be insignificant (except for significance at 10% and a positive coefficient for small companies). This result is similar to the findings in Harrison et al. (2008) for France, Germany, the United Kingdom, and Spain, and in Dachs and Peters (2013) for Europe in general. In Leitner et al. (2011) it would appear to be significant for all European countries included in the sample (significant at 10%) and those in southern Europe (significant at 5%), with a positive impact in both cases.

When we look at the effect on skilled and unskilled employment in Uruguay, we find that product innovation continues to be significant in all cases, but the coefficients are lower in the case of unskilled labor, similar to the results in Leitner et al. (2011) for all European countries and southern European countries. Process innovation has a net displacement effect only in the case of unskilled labor for the entire sample. In all other cases, it has no effect. This evidence for Uruguay supports the hypothesis that innovation in the service sector is skills-biased (against unskilled work) and is in keeping with the findings in Evangelista and Savona (2003) for Italian companies.

TECHNOLOGICAL CHANGE

In this section, we will put aside the analysis of historical evidence on the link between technological change, innovation, and the labor market by taking a forward-looking approach. We will focus on the impact that technological change could have on labor markets in Argentina and Uruguay, paying particular attention to the substitution or replacement of the occupations that are currently carried out in these countries.

We will try to get a sense of the scale strength of technology-related job destruction, or "technological unemployment," and to identify the population groups and activity sectors that are most exposed to this phenomenon. We will then try to understand the challenges that this new employment context poses to the social protection system with the aim of contribute to minimizing the impacts of this transition.

To do so, we will use an empirical strategy based on the recent results of the study by Frey and Osborne (2013). This publication is a major benchmark in the recent literature on technological change and employment. Indeed, although it was originally developed for the United States, it has been used as the basis for several subsequent studies to estimate how vulnerable current jobs are to technological change in different

TABLE 4
INNOVATION AND EMPLOYMENT IN SERVICES, URUGUAY VS. EUROPE

DEPENDENT VARIABLE: EMPLOYMENT ADJUSTED FOR GROWTH IN SALES OF OLD PRODUCTS

INNOVATION VARIABLE	GROWTH IN SALES DUE TO NEW PRODUCTS	PROCESS INNOVATION ONLY[1]
ABOAL ET AL. (2015)		
ALL COMPANIES	0.95***	1.21
SMALL COMPANIES	0.83***	6.94*
KNOWLEDGE-INTENSIVE COMPANIES	1.03***	1.52
DACHS AND PETERS (2013) 2/		
EUROPE (16 COUNTRIES)	0.89***	-1.57
LEITNER ET AL. (2011) 3/		
ALL	0.69***	1.67*
CEEC	0.91***	3.44
CORE	0.89***	-0.68
SOUTH	0.42***	3.38**
HARRISON ET AL. (2008) 4/		
FRANCE	1.23***	-1.63
GERMANY	0.90***	1.56
SPAIN	1.07***	-0.46
UNITED KINGDOM	1.10***	3.10

Notes: Estimation by instrumental variables. *, **, ***: significant at 10%, 5%, and 1%, respectively. Process-only innovation is a dummy variable that indicates the introduction of process-only or organizational innovation by firms.
1: Harrison et al. (2008) and Aboal et al. (2015) include organizational innovation as part of the process innovation variable.
2: Europe: data for firms from 16 European countries. Source: Table 3 column (1), services.
3: All: includes Denmark, Estonia, France, Greece, Hungary, Italy, Latvia, Luxembourg, Portugal, Slovenia, Slovakia, Spain, and Sweden; CEEC: Czech Republic, Estonia, Hungary, Latvia, Slovenia, and Slovakia; CORE: Denmark, France, Luxembourg, and Sweden; South: Greece, Italy, Portugal, and Spain. Source: Table 2.
4: Source: Table A2.

TABLE 5
PROBABILITY OF AUTOMATION WITHIN OCCUPATIONS

	WOMEN	MEN	TOTAL
ARGENTINA	61.3%	66.1%	64.1%
URUGUAY	63%	69.2%	66.4%

Source: Compiled by the authors based on Frey and Osborne (2013) and permanent household surveys for Argentina and Uruguay in 2015.

countries. Although there are significant limitations to our approach (see box), it provides us with a measure of the relative vulnerability of the labor markets of Argentina and Uruguay and enables these to be compared to a large set of countries.

The study by Frey and Osborne (2013) reports on the probability of a set of occupations being computerized or replaced by robots in the medium term. The occupations in question are based on the International Standard Classification of Occupations (ISCO). Taking these probabilities as a reasonable approximation for what might be expected to take place in the coming decades regarding the advance of technology on existing jobs, we sought to quantify the vulnerability of the current labor markets in Uruguay and Argentina.

Specifically, we mapped the information in Frey and Osborne (2013) onto data from the Permanent Household Surveys for Uruguay and Argentina. This mapping required the creation of correspondence tables between the occupational classifications used in the data sources.[1] Once each person in employment had been assigned a probability of their current job being replaced, aggregate substitution probabilities were computed

TABLE 6
PROBABILITY OF OCCUPATIONS BEING AUTOMATED BY AREA OF ACTIVITY

	ARGENTINA	URUGUAY
AGRICULTURE LIVESTOCK FARMING, HUNTING, FORESTRY, SILVICULTURE, AND FISHING	63.2%	82.2%
MINING AND QUARRYING	66.%	70.2%
MANUFACTURING	73.7%	74.8%
ELECTRICITY, GAS, AND WATER	69.3%	67.%
CONSTRUCTION	66.%	72.5%
WHOLESALE AND RETAIL TRADE REPAIRS	76.6%	80%
TRANSPORTATION AND STORAGE	76.6%	72.2%
HOTELS AND RESTAURANTS	66.6%	76.3%
COMMUNICATIONS	51.4%	51.9%
FINANCIAL ACTIVITIES	67.%	79.%
REAL ESTATE	53.6%	75.7%
OTHER SERVICE ACTIVITIES	54.1%	52.7%
EXTRATERRITORIAL ORGANIZATIONS	77.6%	59.8%

Source: Compiled by the authors.

LIMITATIONS OF FREY AND OSBORNE'S APPROACH

The study by Frey and Osborne (2013) at the University of Oxford and the probabilities they calculate in it are a major benchmark in the recent literature on technological change and employment. Indeed, it has been used as the basis for several subsequent studies to estimate how vulnerable current jobs in different countries are to technological change. However, recent studies carried out by the OECD (see, for example, Arntz, Gregory, and Zierahn, 2016; and OECD, 2015, 2016) have pointed out some major limitations to Frey and Osborne's approach. The most significant aspects of this criticism are as follows.

First, the authors point out that Frey and Osborne's (2013) occupation-based approach implicitly assumes that an entire occupation would be replaced by technological progress, rather than the specific tasks that an occupation entails. This assumption could lead to a significant overestimation of the effects of technological change on employment.

Based on this new task-based approach, the study by Arntz et al. (2016) finds, for example, that only 9% of occupations in the United States run the risk of being automated, in contrast with the 47% estimated by Frey and Osborne (2013).

Second, Arntz et al. argue that Frey and Osborne (2013) directly associate the technological substitution of jobs with job loss. Arntz et al. (2016) argue that the automation of certain tasks does not necessarily imply that human labor is being replaced by machines, but just that tasks are being divided differently between the two.

for all people in employment and for different subgroups of the population, which allowed us to identify sectors that are particularly vulnerable to technological unemployment.

The findings from this exercise indicate that approximately two-thirds of the occupations that currently exist in Argentina and Uruguay run the risk of being replaced by technological progress. In addition, technological unemployment would be a widespread phenomenon affecting all areas of activity, meaning that there would be no area where the probability of substitution would be below 50%. One additional concern is that no inverse correlation was observed between age and the probability of technological unemployment. In other words, young people in Uruguay and Argentina are continuing to enter occupations where there is a high risk of their being replaced by machines.

Finally, given that there is a notable (negative) correlation between the probability of technological unemployment and education levels, it would seem that education is increasingly necessary for people to attain less vulnerable positions in the labor market. This exercise sought to approximate the vulnerability of the occupations currently being performed in Uruguay and Argentina vis-à-vis technological progress.

First, we calculated the average probability of all those employed in each country being replaced by computers or technology. This approximation revealed a high-risk outlook in which, on average, approximately two-thirds of all occupations currently being performed in both Argentina and Uruguay may be automated in the medium term (see table 5). It can also be seen that in both countries men are, on average, employed in occupations where the risk of automation is higher. However, even the probability of womens' jobs being automated was above 60% on average in both Argentina and Uruguay.

These figures are notably higher than even the already high values calculated by Frey and Osborne (2013) for the US economy, where the probability of technological unemployment applied to around 47% of occupations. They are also higher than the values estimated for other developed economies (35% in Finland according to Pajarinen and Rouvinen, 2014; 59% in Germany according to Brzeski and Burk, 2015; and between 40% and 60% for economies in southern Europe according to Bowles, 2014). The fact that the Río de la Plata economies are more vulnerable to technological change than the United States and other more developed economies may be due to both supply and demand factors.

As technological change is a continual process, it may be the case on the labor demand side that in the United States the process of automating certain occupations is at a more advanced stage of development and there is thus no longer demand for occupations where there is a high probability of human workers being replaced.

Likewise, given that wages are higher in developed countries, there may be a greater incentive to move ahead with automation processes in these economies than in economies where wages are lower. Indeed, in countries with lower wages, it may not be profitable to invest in automating tasks even if the technologies are available. Finally, more developed economies may concentrate their production and employment in sectors that are intensive in less routine jobs, where robotization is harder.

TABLE 7
PROBABILITY OF OCCUPATIONS BEING AUTOMATED BY LEVEL OF EDUCATION

	ARGENTINA	URUGUAY
PRIMARY	71.3%	73.7%
PARTIAL SECONDARY	71.4%	73%
COMPLETE SECONDARY	71%	68.3%
PARTIAL UNIVERSITY	66.2%	60.2%
COMPLETE UNIVERSITY	39.9%	29%

Source: Compiled by the authors.

TABLE 8
PROBABILITY OF OCCUPATIONS BEING AUTOMATED BY AGE GROUP

AGES	ARGENTINA	URUGUAY
15-30	72.9%	74.7%
31-40	65.9%	65.9%
41-50	62.3%	64.2%
51 OR OVER	61.9%	65.5%

Source: Compiled by the authors.

On the supply side, the higher average skill levels of the labor force in developed economies has probably helped workers find employment in more complex occupations, which are less routine, and thus harder to automate.

These hypotheses regarding the increased vulnerability of the labor markets of Argentina and Uruguay are not analyzed in this article, although it would be useful to attempt to understand the importance of each of these factors to better understand how to mitigate current vulnerability.

MOST VULNERABLE GROUPS

An analysis of the population that is currently in employment with a focus on different characteristics such as age, gender, area of activity, and level of education reveals highly varied circumstances and thus groups that are more vulnerable to automation.

With regard to areas of activity, taking a relatively high level of aggregation as a reference, there are no major sectors where the probability of automation appears to be lower. In other words, no major activity sector can be identified in which there is a lower likelihood of the future technological substitution of jobs. Indeed, as can be seen in table 7, the automation probability for all the major activity sectors in the International Standard Industrial Classification of All Economic Activities (ISIC) in Argentina and Uruguay is above 50%.

However, within this global outlook, there are significant variations within each area. In both Uruguay and Argentina, there are areas of activity where the risk of technological unemployment is around 80%, while in other areas this figure comes down to near 50%.

The most extreme case is in Uruguay, where the probability of jobs being replaced in the agriculture, hunting, forestry, silviculture, and fishing sector is higher than 80%. The figures are similar for the wholesale and retail trade and repairs and financial activities. The areas of activity where there is less probability of jobs being automated are communications and all other service activities, where the average probability is around 50%.

In Argentina, the activities where occupations are at the greatest risk of technological replacement (above 75%) in all cases are wholesale and retail trade and repairs; transportation and storage; and extraterritorial organizations. As in Uruguay, the probability of jobs being automated is lowest in the communications sector and all other service activities, a group which in Argentina also includes real estate activities, with technological job replacement probabilities of just over 50%.

If we look at levels of education, there is a predictable negative correlation between this and the probability of technological substitution. This relationship follows a very similar pattern in both Río de la Plata countries (see table 6).

One interesting factor worth considering is that although the negative relationship between education levels and the probability of technological job replacement can be seen at all levels, this probability is only noticeably lower among those with complete university education. Indeed, even workers with incomplete university education are still employed in jobs where there is a high probability of automation in the medium term.

In this sense, although from the supply side more education would seem to be the best strategy for finding a job that is less vulnerable to technological unemployment, this strategy only significantly reduces vulnerability if workers obtain a complete university education.

Finally, the analysis of vulnerability to technological unemployment by age group reveals an additional concern. While the most desirable situation would be to find a positive correlation between age and the probability of technological job replacement, the outlook is in fact neutral in Uruguay and there is even a negative correlation in Argentina.

In other words, on average, young people in Uruguay and Argentina are not entering more modern occupations that are less exposed to technological unemployment than earlier generations. Instead, they are continuing to find employment in occupations where there is a high risk of workers being replaced. This phenomenon is particularly worrying, given that the challenges that automation poses to the social security system would evidently be lowest if the people who are most exposed to technological employment were close to retirement age (see table 8).

POLICY CHALLENGES

The evidence available for developing countries and Latin American countries indicates that innovation is key to countries' productivity growing. The literature available for Latin America indicates that product innovation has had positive effects on employment at the firm level, while process innovation has generally had a neutral impact. However, there is fairly clear evidence that innovation is skills-biased—that is, it favors demand for more skilled labor.

The simple exercise carried out in this article based on Frey and Osborne's (2013) approach indicates that many current occupations in Argentina and Uruguay are at risk of disappearing in the medium term due to technological progress. However, the amount of time it will take for the labor market to transform may vary significantly depending on the cost of technology, the cost of labor, and the availability of human resources that have adapted to the new conditions.

The literature warns that the only jobs that will tend to endure and grow in the labor market over the coming decades are those that entail nonroutine tasks, particularly in areas involving cognitive labor.

Given this context, there are three

61%

OF THE JOBS PERFORMED BY WOMEN IN ARGENTINA RUN THE RISK OF BEING AUTOMATED

major policy challenges ahead. First, adapting the labor force to the new demands of the 21st century. Second, minimizing the costs of transitioning toward these new circumstances. Finally, finding institutional arrangements that allow society to benefit from the advantages of technological change. Generally speaking, such change tends to improve social welfare and bring opportunities for reducing poverty. However, without suitable political solutions to the problems described in this article, we may instead witness a situation characterized by growing inequality in which technological gains are not enjoyed by all of society.

The first major challenge facing our economies is thus helping the labor force to acquire the new skills they need. Modern economies require workers with modern skills. Workers in the 21st-century will need more cognitive, technical, and socio-emotional skills if they want to find better jobs. Likewise, given the greater speeds at which acquired skills depreciate, training and education need to become ever more continual, with a greater emphasis on lifelong learning.

Most Latin American countries have increased their education budgets to this end. In recent years, there has also been greater assessment of educational systems, and the different policies that have been implemented focus mainly on developing students' cognitive abilities. The OECD's PISA tests have played a fundamental part in this transformation by measuring the results obtained by different education systems in a comparative fashion. In other words, education systems are paying increasingly less attention to student's capacity for assimilating information and are instead concentrating on their ability to understand it and process it so as to solve practical problems.

In addition to this increased orientation toward obtaining better results in cognitive skills training, several countries have tried to incorporate new information technologies into their education systems to reduce the digital divide between students. For example, the One Laptop per Child project, which aims to provide each student with a low-cost laptop, has met with widespread acceptance in Latin America.[2]

The workers who will be most affected by the transition toward the new demands of the labor market are those in middle age whose skills have depreciated significantly in value. If these workers were to lose their jobs, it would be particularly difficult for them to find new ones. This situation poses a serious challenge in terms of social protection and supply-side labor policies if we are to avoid consolidating a group of people that are excluded from the labor market and exposed to economic vulnerability.

To handle this transition, supply-side labor policies are needed to provide displaced workers with new skills that meet the market's new requirements, along with the promotion of entrepreneurs and new, independent forms of employment. To date, there have been no significant transformations in social security systems that are oriented toward dealing with potential mass technological unemployment.

Finally, even if we discard the possibility of mass technological unemployment as an outcome of this new technological revolution, what lies ahead may be a new situation with lower levels of demand for work. However, we need to consider that less demand for labor does not necessarily imply a reduction in worker numbers, but may instead involve a more balanced solution in which people work shorter hours. Indeed, reducing the working day as labor becomes more productive seems to have been the way that several European countries have been approaching such phenomena in recent decades (Spezia and Vivarelli, 2000).

NOTES

[1] Correspondence table between the SOC-2010 and ISCO 08 classifications to map Uruguay's Permanent Household Survey and another between Argentina's National Occupation Code CNO 01 (*Código Nacional de Ocupaciones 2001*) and ISCO 08 to map Argentina's Permanent Household Survey.

[2] Versions of this project have been undertaken to different extents in several Latin American countries, including Uruguay (Plan Ceibal), Peru, Nicaragua, Ecuador, Colombia, Venezuela, and Argentina. China and India have also implemented the project.

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ANALYSIS

Crowd-b capitalism

Men are not born in order to die
but in order to begin.

Hannah Arendt

Arun Sundararajan
New York University

based

THE AUTHOR OF AN INTERNATIONAL BESTSELLER ON THE SHARING ECONOMY EXPLAINS THE ROLE THAT TRUST PLAYS IN NEW DIRECT PARTICIPATION SYSTEMS. HE ALSO ANALYZES THE MOST POPULAR SHARING ECONOMY PLATFORMS IN LATIN AMERICA AND CALLS FOR APPROPRIATE PUBLIC POLICIES TO PROMOTE AN INNOVATION ECOSYSTEM BASED ON A MULTIFACETED, INCLUSIVE SOCIAL CONTRACT.

Over the last decade, a new class of digitally-enabled exchange has emerged across a wide variety of industries. As of early 2017, over 100 million people have found short-term accommodation through the platform Airbnb, and through similar UK-based platforms LoveHomeSwap and OneFineStay. China's ridesharing platform Didi Chuxing (a strategic investor in Brazil's 99Taxis and Dubai's Careem) now facilitates more rides per day than giant Uber, both having mediated billions of rides across hundreds of worldwide. Numerous local platforms include Ola (India), GoJek (Indonesia), Grab (Singapore), Cabify (a dozen Central and South American countries ranging from Panama and Ecuador to Brazil and Argentina) and Tappsi (Colombia). The France-based ridesharing platform BlaBlaCar, which expedites city-to-city transportation, now has 35 million members in 22 countries and operates on a daily scale comparable to that of a national transportation network.[1]

Peer-to-peer car rental platforms Drivy (in France and Germany), SnappCar (in the Netherlands), SocialCar (in Spain), Arriendas (in Chile), Getaround, and Turo (in the US) compete with fleet-based car rental companies around the world. Social dining apps EatWith (in Spain) and VizEat (in France) provide a platform-based peer-to-peer alternative to restaurants.

Individuals are becoming small-business lenders through UK-based peer-to-peer lending platform Funding Circle, venture capitalists through a range of crowdfunding platforms that include AngelList (US), CrowdCube (UK), Derev (Italy), FundedByMe (Sweden) and MyMicroInvest (Belgium), and support projects they believe in through crowd-based platforms like IdeaMe (numerous Central and South American countries), Fondeadora (Mexico), Catarse (Brazil), and Kickstarter (US). A wide variety of specialized labor platforms are creating new opportunities to run a business of one, in industries as varied as in-home services (Aliada in Mexico, Handy in the US), interior design (CoContest in Italy) and management consulting (Catalan in the US).

These activities—peers giving each other a ride, a place to stay, a meal, a loan, help with home improvement—are not new. What is new, however, is the emergence of digital platforms that grow such peer-to-peer activity to the level where the platform-based exchanges rival the industry-leading corporations. For example, on December 31, 2016, over 2 million people were staying in an Airbnb—someone's bedroom or home rented through the Airbnb platform—as a way of getting accommodation in a city or town they were visiting for New Year's Day. (As a point of comparison, the world's largest hotel chain, Marriott-Starwood, has just 1.1 million rooms.)

Such exchange is reminiscent of how the world's economic activity was organized prior to the Industrial Revolution, when a significant percentage of economic exchange was peer-to-peer and intertwined in different ways with social relations, and when the trust needed to make economic exchange possible came primarily from social ties of different kinds.

The transition to large corporations with full-time employees is even more recent: engaging in some form of small-scale entrepreneurship was very common until the turn of the 20th century. In fact, in 1900, almost half of the compensated US workforce was self-employed. By 1960, this number shrank to less than 15% (see figure 1).

I call this new way of organizing the world's economic activity "crowd-based capitalism." One might wonder why there is a need for a new term when many people already refer to these activities as being part of the "sharing economy" or "collaborative economy." As I studied what was called the "sharing economy" between 2011 and 2015, a frequent conversation at conferences and in the popular press was about what set of activi-

35

MILLION PEOPLE ARE MEMBERS OF THE FRENCH RIDE-SHARING PLATFORM BLABLACAR

ties, business models, or economic systems this term actually encompassed and whether it was, in fact, an appropriate label for commercial businesses like Uber and labor markets like Upwork whose connection to "sharing" seemed tenuous at best. However, as I explain in Sundararajan (2016): "Although I find 'crowd-based capitalism' most precisely descriptive of the subject matter I cover, I continue to use 'sharing economy' as I write this book because it maximizes the number of people who seem to get what I'm talking about."

I believe that crowd-based capitalism could radically transform what it means to have a job, reshape our regulatory landscape, and challenge a social safety net funded by corporate employment. The way societies finance, produce, distribute, and consume goods, services, and urban infrastructures will evolve. New ways of organizing economic activity will redefine whom we trust, why we trust them, what shapes access to opportunity, and how close we feel to each other. Most importantly, there is a two-pronged assault on salaried employment—the rise of nonemployment work and the increasing cognitive capabilities of machines—that will make it necessary for society's model of earning a living to evolve. Crowd-based capitalism may be the answer.

The Digitization of Trust

The dramatic rise of crowd-based capitalism can be attributed in part to dramatic improvements in our ability to get people to trust others they don't know through the use of different systems generating reliable digital cues that together might be thought of as the "digital trust grid."

It helps at this point to define "trust." Of course, in many ways, the definition depends on the context. Trust in a romantic relationship might mean something different from trust in a commercial transaction. A particularly useful definition in the context of crowd-based capitalism comes from the sociologist James Coleman (1994), who defined trust as "a willingness to commit to a collaborative effort before you know how the other person will behave."

Establishing trust depends on a multiplicity of dimensions. In a non-face-to-face (and sometimes face-to-face) setting, it first involves establishing authenticity. Is this provider real? Are they who they say they are? Second, it involves assessing intentions. Do these providers have good intentions or are they looking to steal from me or harm me? Third, it involves assessing expertise or quality. Is this person a good designer? Are these people truthfully representing how interesting their neighborhood is? Are they polite? Is that investor as experienced as she claims? Does the car have as much legroom as the photo indicates? Put differently, trust relies on verifying identity, intentions, and capabilities. I have proposed in the past that this process of verification in semi-anonymous internet-based peer-to-peer settings stem from multiple cues. These cues include learning from one's own prior interaction; learning through familiarity that comes from the nature of exchange being part of the "cultural dialogue"; learning from the explicit experiences of others; learning through brand certification; learning by relying on digitized social capital; and the reliance on digitized forms of real-world identity, validation from external institutions or entities, government and nongovernment, digital and otherwise (see figure 2).

In many ways, the lower the stakes of the interaction, the easier it is to establish sufficient trust. This is why platforms such as eBay scaled early—the stakes are lower when buying a product from a stranger than when getting into a stranger's car and saying, "drive me to another city." While we have had digital access to some of these sources of trust for some time—arguably since peer-to-peer platform eBay was established in 1995—the final two have become digitally available at scale only recently.

In many countries, the government, of course, plays a central role in the validation within the final trust cue, in part through regulation of different forms. But to better interpret some of the stances around government regulation and trust, it is important to understand that regulation is an evolving system with an eclectic history—a history that has often involved social factors. Consider the example of Maghribi traders, who played a leading role in world trade in the 11th century. Competitive advantage at that time depended on the ability to ship goods without traveling with them. A good relationship with an overseas agent—whose actions once a shipment arrived could not be tracked—was key.

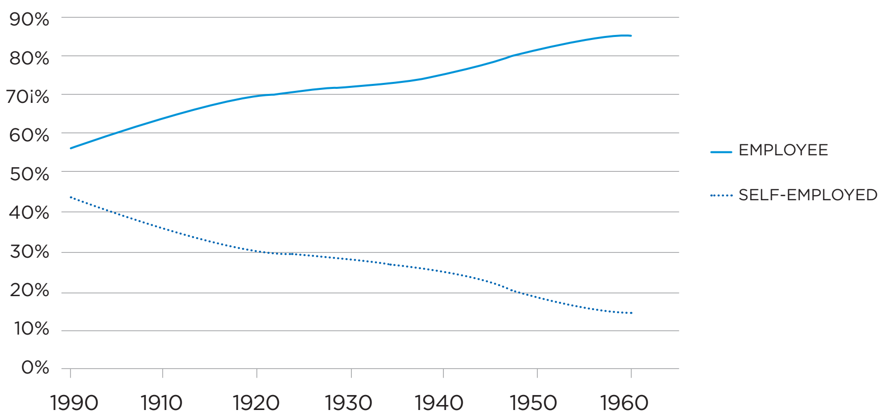
This medieval trading community holds important lessons for the 21st-century platforms. In both cases, we are faced with the challenge of establishing trust provisions in markets that stretch across geographic and cultural boundaries. A combination of reputation and self-interested community created the trust provisions that would govern the behavior of overseas agents. Trust was built by creating a situation where one's reputation mattered (overseas agents known for corruption would over time fail to profit), and trust was built by creating communities of shared interest that connected reputation to economic self-interest (the formation of merchant coalitions who adopted common hiring policies and penalties meant corrupt overseas agents had more to lose).

25%

OF WORK IN THE UNITED STATES IS PERFORMED BY FREELANCERS

Crowd-based capitalism is distinguished from other digital revolutions that preceded it in that it creates new ways of providing familiar services that are traditionally

FIGURE 1
PAID US WORKFORCE, 1900-1960



Source: Sundararajan (2016).

often highly regulated. As a consequence, regulatory conflict is to be expected, and indeed, around the world, governments have struggled with how to best regulate this new form of exchange. This historical parallel is provided to underscore the fact that today's shift to the platform-mediated world, with its new social aspects, introduces new trust challenges but also provides new solutions to existing trust challenges.

In summary, regulation, often interwoven with the provision of trust, doesn't always have to originate with governments. Regulation can take on myriad forms, governmental and otherwise. Responding to this ongoing shift requires a fundamental rethinking of how we regulate. We may need to imagine a regulatory system that works with, rather than against, the crowd-based platforms that are tomorrow's institutions.

CONVERGING PLATFORMS

These crowd-based institutions will assume a greater level of importance for employment and trade in the coming years. In economies around the world, two of the 20th century's primary forms of human employment—farming and manufacturing—have been steadily subjected to increasing automation over the last 100 years. And today, an even more menacing automation threat comes from the "second machine age" predicted by Erik Brynjolfsson and Andrew McAfee, wherein technologies start to perform the cognitive tasks that used to be the exclusive domain of humans. There are a number of recent early examples of this expansion in machine capabilities. IBM's Watson technology promises artificial intelligence (AI) powered solutions for financial compliance, medical diag-

FIGURE 2
THE DIGITAL TRUST GRID

Source: Sundararajan (2016).

100

US INSTITUTIONS WERE CREATED THROUGH THE MORRILL LAND GRANT ACT

nostics, and legal services. We see self-checkout counters at a growing number of retail stores. Self-driving automobile technologies seem poised to threaten tens of millions of trucking jobs globally.

The labor displacement effects of automation are likely to be exacerbated by the growth of the fraction of the workforce engaged in nonemployment work arrangements. Estimates of the total number of such "independent" workers in the United States range from 40 million to 68 million. In fact, according to one influential recent study by Alan Krueger and Larry Katz (2016) of Princeton, almost all of the net "employment" growth in the United States between 2005 and 2015 seems to have occurred in these kinds of new work arrangements. Whichever estimate one embraces, the arrangements already represent between 25% and 40% of the US civilian labor force of 160 million.

This recent trend towards nonemployment work arrangements is accompanied by another threat to salaried employment: the decomposition of work into "tasks" or "projects." In the past, hiring thousands of workers on short-term contracts to carry out small slices of work was simply unfeasible because of the high administrative and transaction costs it entailed. Today, however, numerous digital platforms are enabling this deconstruction, especially for more complex tasks and project work. There is the global leader, Upwork, which has over 12 million registered freelancers offering skills ranging from administration and customer service to web development and accounting, as well as country-specific platforms like Crowdworks and Lancers in Japan (both of which boast over a million workers apiece).

A growing number of professional labor platforms are also targeting specific industries. Using Catalant for management consulting, Gigster for high-end software development, and UpCounsel for legal services, it is now possible to reimagine what might have been work arrangement involving full-time employees as one that is instead a succession of short-term contracts with best-of-breed providers. The popularity of crowd-based platforms in specific verticals like transportation that enable many services to be provided seamlessly on an as-needed basis may further lower the need for certain kinds of employment (like full-time corporate drivers).

There are many reasons why the *confluence* of these two forces—automation and nonemployment work arrangements—will more disruptive than the sum of the effects of each in isolation. First, the pace at which human work may be displaced by automation could be increased when the strength of the relationship between the human and the institutional source of demand for the labor is weakened. It is easier for an organization to terminate independent contract workers than full-time employees.

Second, at a specific level of technological progress, different tasks that comprise a job are automatable to different degrees. Work arrangements that involve full-time and long-term employees allow for greater slack in the design of work systems: the people performing the tasks are co-located, there is a greater level of fault tolerance, and it is also consequently harder to isolate the specific tasks suited for automation immediately and more challenging to seamlessly replace the associated human labor with a machine. In contrast, if the work associated with today's full-time jobs is "unbundled" and farmed out to on-demand labor platforms, this must necessarily be accompanied by a far more structured production process, one that is designed to make tasks more separable and modular. This will naturally increase the pace and precision at which such tasks can be automated when the technology is ready.

Third, certain work arrangements lower the collective bargaining power of labor due to legal rather than economic reasons. The prospect of impending automation, which translates into an increase in the rate at which capital can be substituted for labor or talent, puts downward pressure on the wages associated with the provision of this labor or talent. With lower labor bargaining power, the realized negative effect on wages will be more pronounced, lowering the desirability of being a labor or talent provider.

REFASHIONING THE SOCIAL CONTRACT

Faced with the prospect of this multifaceted attack on their primary model of work, any country needs to start to rethink how its citizens earn a living. The shift must be away from humans earning money by providing their labor and talent to a large organization which owns the capital associated with the economic activity, and towards an economy in which the humans are capital owners, running tiny businesses, ones that use a mix of labor and talent inputs, some of which might come from the individual themselves, and some of which might come from other humans (perhaps even via an on-demand platform). Under this future model, as an increasing fraction of these inputs shift away from human labor and towards AI and robotics technologies, the humans may still retain their ability to earn a living if they can retain their ownership of the capital.

Let me explain that final point

about capital ownership a little further. As the scale of a provider is reduced to that of an individual microbusiness, and what used to be enabled by government regulation and economic institutions is often facilitated by the trust systems the platform provides, the intellectual capital and intangible capital held by organizations is redistributed between platforms and individual microbusinesses. In some cases, like that of transportation services using Uber, much of this capital remains with the large institution, the platform. In other cases, like that of short-term accommodation businesses run through Airbnb, or retailing businesses through Etsy, the provider appears to hold a greater fraction of this capital.

This division of intellectual capital between the platform and the provider is a central determinant of an equitable future of work. One way to understand its importance is through the lens used to study inequality shifts by French economist Thomas Piketty. At the core of his 2014 book *Capital in the 21st Century is* a simple argument: inequality persists because the historical returns on capital (r) are persistently higher than the overall rate of growth (g) in the economy, while the rate of growth of wages that are paid in exchange for labor and talent is roughly the same as this overall rate of growth (g). As articulated by Piketty (2014): "The inequality r > g implies that wealth accumulated in the past grows more rapidly than output and wages. This inequality expresses a fundamental logical contradiction. The entrepreneur inevitably tends to become a renter, more and more dominant over those who own nothing but their labor. Once constituted, capital reproduces itself faster than output increases."

50%

OF US WORKERS IN 1900 WERE SELF-EMPLOYED

This observation, aimed at explaining the persistent recent rise in income and wealth inequality, also highlights the promise of a crowd-based capitalism that genuinely decentralizes the ownership of capital. It can increase the fraction of a workforce that makes money through investing or owning rather than providing labor in exchange for a salary, allowing a greater fraction to occupy new locations in the established economic equation, moving from wage receivers to capital owners, thus expanding the fraction of the population that have the "r" kind of growth in their returns rather than the "g" kind.

Preparing for this new digital future of work necessitates a shift in the focus of postsecondary education away from one-time early life degrees and towards continuing education. Recent political outcomes in the US and the UK reflect in part a significant underinvestment into creating new opportunities for a workforce displaced by automation and ill-equipped for a new world of work. We need new university-like institutions that can fill this gap, providing individuals in transition with structured and pedagogically sound education accompanied with a new professional network and access to new opportunities, facilitating relocation to pursue a new career more naturally, imbuing workers in flux with a new identity and sense of purpose, rebuilding self-worth to allow transition with dignity.

Creating such an ecosystem will necessitate the right government interventions. It is not realistic to expect a slew of robust new continuing education institutions to emerge naturally. The managerial revolution of the 20th century in the United States was made possible in part by the federal subsidies given to states under the Morrill Land Grant Act of 1862 which spawned over 100 land-grant institutions that still exist today (and that include some of the country's top educational institutions like Cornell, MIT, Ohio State University, and the University of Minnesota). Although these institutions perhaps did not immediately fulfill their stated goal of teaching "agriculture and the mechanical arts," the act laid the foundations for a nationwide and broadly accessible postsecondary university system. A similar intervention aimed at preparing us for this new future of work is needed.

Finally, the social contract must be refashioned to accommodate a different kind of workforce. During the second half of the 20th century, a variety of labor laws were developed to improve the quality of work life for full-time employees, including minimum wages, overtime, and insurance. A number of other incentives that fulfill different human aspirations—fixed salaries, paid vacations, workplace training, and healthcare—are funded based on the assumption that the model of work is full-time employment and the employer will fund all or part of the incentive.

The design and funding of this social safety net must be adapted for a workforce that is increasingly independent, while also creating substitutes for the career paths and community that a growing fraction of the workforce now gets from the company that they work for. Perhaps the role of the postsecondary university will evolve to include this kind of lifelong career planning.

NOTES

[1] This article is based on the bestselling book *The Sharing Economy: The End of Employment and the Rise of Crowd-Based Capitalism* (Sundararajan, 2016) and examines some issues from this in greater depth based on recent developments in the sharing economy.

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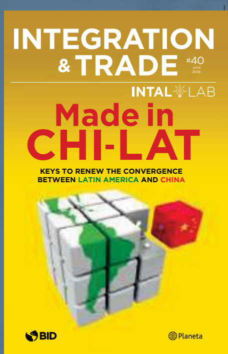

The new normal for the Chinese economy and the future of the country's relations with Latin America and the Caribbean

Inspired by the papal encyclical *Laudato Sí*, experts from around the world put forward concrete ideas for moving toward an eco-friendly form of integration

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ANALYSIS

metan

José Manuel Salazar-Xirinachs
Regional director of the ILO for
Latin America and the Caribbean

The
morphosis
of
work

We are being afflicted with a new disease of which some readers may not yet have heard the name, but of which they will hear a great deal in the years to come—namely, technological unemployment.

John Maynard Keynes

The world of work is experiencing enormous transformations that will continue and may well intensify into the future. The world of work is being globalized, digitalized, robotized, decarbonized, and also "fissured" or outsourced (Weil, 2015)—in other words, radically transformed by a series of factors. These can be summarized into five groups of factors that influence the present and future of work: demographic and population factors; technological factors; countries' productive development (or underdevelopment); new business models and forms of hiring; and the political outlooks of social actors and processes of social dialogue. This article analyzes each of these factors.

Demographics is one of the most exact sciences due to the Law of Large Numbers and the stability of demographic structures, at least in the absence of catastrophes. Figure 1 shows the enormous demographic transition that Latin America and the Caribbean has undergone and will undergo in the 150 years between 1950 and 2100. The population's tendency toward ageing is notable: in 1950, 3% (5 million people) of a total population of 162 million were older adults (aged 65 and over); in 2000, this group accounted for 6% of the total (30 million out of 512 million); in 2050, it is expected to represent 20% (155 million out of 776 million); and by 2100 it will have grown to 30% (204 million out of 680 million).

In contrast, the young population (those aged 15 to 29) has been decreasing since the end of the 1990s, a trend that has become more pronounced since 2010. Although this segment currently represents 29% of the total population, it will come down to 22% by 2050. In fact, 2050 will be a landmark in that it will be the year in which the share of adults over 65 begins to exceed that of young people between 15 and 29 years of age for the first time in the region's history.

What does this mean for the world of work in Latin America and the Caribbean? Nothing short of revolutionary change. First, the dizzying growth of the old adult population may be an opportunity for job creation as it will prompt an increase in the demand for occupations in the health and care economies, such as doctors, nurses, physiotherapists, and hospital and "assisted living" services. The political challenge will be to ensure that the jobs created in these occupations are high quality ones at public and private institutions that operate within the formal care economy. This which will require significant investments in infrastructure, regulatory frameworks, and also in education and vocational training to create the labor force for this new and significantly larger care economy.

Second, at the other extreme of the population pyramid, most countries in the region are still experiencing the so-called "demographic bonus": the potential advantage of a large young

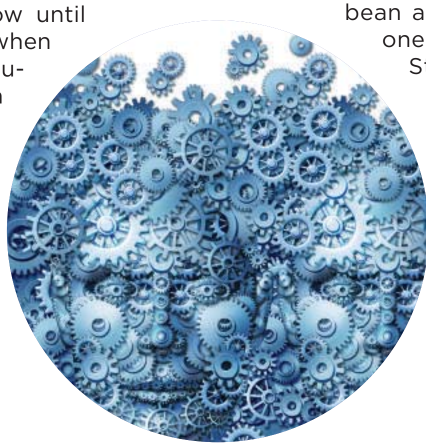
30%

OF THE POPULATION OF LATIN AMERICA AND THE CARIBBEAN IN 2100 WILL BE OLDER ADULTS

population that is entering the labor market. However, this possible boost to growth and well-being will only become a reality if young people are educated and youth unemployment rates remain low. The high rates of youth unemployment and large numbers of NEETs (young people who are not in education, employment, or training) suggests that Latin American countries are not taking full advantage of the demographic bonus (ILO, 2013). In several countries, quite the opposite is true: not only is the demographic bonus not being used effectively, it is metamorphosing into criminality, informality, unemployment, migration, and a "lost generation," which are affecting a large swathe of the population due to a lack of opportunities for productive employment.

Third, the transition that will be taking place from now until 2050 and beyond, when the ageing of the population converges with the end of the demographic bonus, will significantly increase the "dependence rate." In other words, an ever-larger share of older adults will depend on an ever-smaller share of young people to maintain their standards of living and income from pensions, which will result in significant financial pressure on social protection systems. As social protection coverage in most countries in Latin America and the Caribbean is low and a vast segment of workers are informally employed and thus enjoy no protection, what lies ahead is a perfect storm scenario. This points to one of the major challenges in the future of work in Latin America, which is how to continue financing suitable pension and social protection systems for the formal sector while expanding this coverage to groups which currently have no protection, particularly informal workers, and how to establish mechanisms for maintaining this coverage even if there are shifts in employment between the formal and informal economy, and vice versa (Levy, 2017).

In addition to demographic changes, the population is also affected by the migration dynamic, the volume and complexity of which have been expanding and which is closely related to the world of work and the quest for job and income opportunities. A recent ILO report (2016) identifies nine intraregional migratory corridors in Latin America and the Caribbean and two extraregional ones, toward the United States and Spain, and analyzes the evolution of these. The ILO calculates that around 27% of the world's total migrant workers are in the Americas (37 million in North America and 4.3 million in



56%

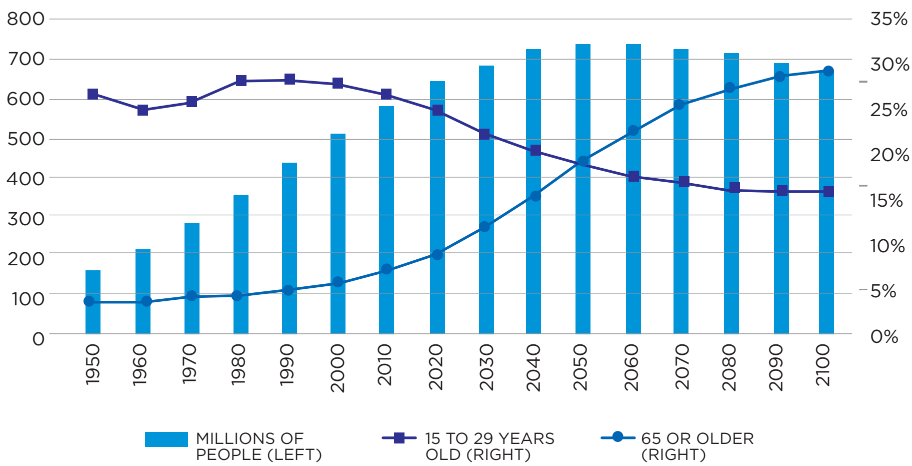
OF WORKERS IN LAC ARE SELF-EMPLOYED OR WORK IN MICROENTERPRISES

Latin America and the Caribbean in 2015), and these numbers are growing fast. The migration corridor system is in constant flux due to changes in economic interdependence and labor markets and is characterized by serious gaps in poverty, income, respect for labor rights, and protection for migrant workers. Although public and governance policies on migrations have expanded and become more complex, they still contain serious weaknesses. There are legal vacuums and migration-related governance is fragmented; the focus on work and rights is weak; players from the world of work are not involved in the consultation processes on migration; there is a lack of coherence between migration and employment policies and coordination failures; and labor market institutions have limited competences in relation to work-related migration. Migratory and labor mobility dynamics are, and will increasingly be, key factors in the world of work and will require the attention of all governments and players within this.

TECHNOLOGICAL FACTORS

Academia, social networks, and the press are being flooded with articles on what the World Economic Forum has called the Fourth Industrial Revolution. A new wave of technological changes is affecting almost all areas of production, including manufacturing, services, and agriculture. For example, in 2013, McKinsey (Manyika et al.) evaluated over 100 possible technologies to identify the 12 with the greatest potential for economic and social

FIGURE 1
LATIN AMERICA AND THE CARIBBEAN: DEMOGRAPHIC TRENDS

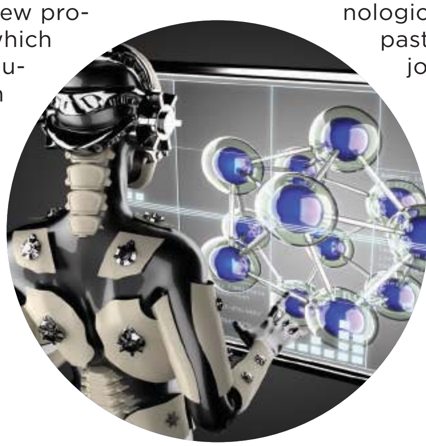


Source: CELADE.

disruption. Their list is as follows: (1) the internet and its impact on information and communications, (2) the automation of knowledge work, (3) the Internet of Things, (4) cloud technology, (5) advanced robotics, (6) autonomous and near-autonomous vehicles, (7) next-generation biotechnology and genomics, (8) energy storage, (9) 3D printing, (10) advanced materials, (11) advanced oil and gas exploration and recovery, and (12) renewable energy. All these technologies will have massive social and economic impacts on business models and the way in which humanity works, innovates, lives, interacts, and studies or is educated—indeed, this is already proving to be the case. All these technologies, and, in some cases, the combination of them, are laying out a new paradigm for global production systems.

But how will the fourth industrial revolution impact the world of work? Much has already been written on this issue and much more is undoubtedly still to be published. There are at least four major issues in the conversation on the impact of technological revolutions: the acceleration of the dynamic of job destruction and creation; the acceleration in the transformation of occupations and the demand for skills; the birth of a new productive paradigms, which in the world of manufacturing has been dubbed Industry 4.0; and the risk of greater inequality.

The dynamics of technological progress have always entailed the destruction and creation of jobs.



Concern over the adverse effects of technological progress on employment has a long and venerable history (Autor, 2014). In 1930, John Maynard Keynes wrote: "We are being afflicted with a new disease of which some readers may not yet have heard the name, but of which they will hear a great deal in the years to come—namely, technological unemployment." The argument today is that things are different this time round, that the process now is and will be much faster because what we are experiencing is not a single technological revolution but several at the same time. Even if the speed of change is not exponential, as many argue, it is at least dizzyingly fast.

There are two coexisting perspectives on this. According to the pessimistic outlook, these changes are exponential, and productive systems and political institutions will not be able to adapt and are lagging behind these changes. Authors such as Brynjolfsson and McAfee (2014) and Ford (2015) represent this view. In one widely cited study, Frey and Osborne (2013) estimate that 47% of jobs in the United States are at risk of disappearing in the next 10 to 15 years.

The optimistic outlook emphasizes that there have been other technological revolutions in the past that have destroyed jobs, but these have also created new ones, and there is no reason to think that things will be different this time. Supporters of this perspective argue that what we lack is economic or sociological imagination to anticipate the marvelous world of new possibilities that lies ahead. The truth of the matter is that this debate lies in the realm of futurology. Neither of the two fields can provide evidence to support either of these positions, and we need to recognize that it is easy both to prophecy Armageddon and to slip into technological flights of fantasy.

However, this has not prevented some recent policy proposals from being put forward. One that has sparked a lot of discussion recently both because of who its proponent is and its controversial nature is Bill Gates's suggestion to tax robots. The idea stems from Gates's skepticism around societies' capacity to manage the automation process. Its objective would be to reduce the speed of this change and use the income from taxing it to retrain workers and finance broader health and education policies. Criticisms of the proposal followed quickly on its heels.[1] Rather than going into the details of the arguments for and against, I would point the reader to this debate as an example of the broad conversation that is unfolding around the impacts of the technological revolution and some possible responses to it.

Robotization is also impacting the balance between insourcing and outsourcing in global value chains, as some processes that are suitable for robotization are returning to developed countries (insourcing or reshoring), where they can now be implemented using limited labor but with high levels of productivity due to robotization. This points to a changing and uncertain map of "winners" and "losers" in terms of employment and the global location of production.

There is a second acceleration that is being caused by technological revolutions: the accelerated transformation of occupations and new skill requirements. The demand for advanced new skills is on the rise and existing skills are fast becoming obsolete. In connection with this, there is debate over how far the new "intelligent machines" will substitute or complement human labor. This line of argument and analysis is based on the distinction between the routine tasks that many jobs entail, based on the assumption that these are easy to automate, and nonroutine tasks, which are harder or impossible to automate. Another distinction is drawn between manual and cognitive tasks, based on similar assumptions. However, the advance of artificial intelligence, speech recognition, and other technologies continue to surprise us by producing (or promising to produce) "machines" that can carry out nonroutine tasks, learning, and moving into cognitive gray areas. Optimists point out that this is opening up a broad range of opportunities for intelligent machines to complement and amplify human abilities while generating new jobs and occupations for humans. For example, Thomas Friedman (2016) puts forward an optimistic vision of complementarity in which the new machines will be "intelligent assistants" for humans in many areas, which will benefit productivity and, in many cases, employment (see Friedman, 2016, chapter 8). The author argues that these intelligent assistants mean that almost all jobs are becoming knowledge work. He also recognizes that this complementarity scenario is something that will not happen automatically, but will require a concentrated effort in terms of public policies, new attitudes toward lifelong learning within companies and individuals, and new social pacts and institutions to bring about the changes and stimulate the investment that will be needed.

The convergence between the Internet of Things, artificial intelligence, robotics, and 3D printing is creating a new production paradigm that is known as Industry 4.0. The potential consequences for the future of production and employment are massive: there are growing numbers of intelligent products (telephones, building materials, wearables, cars) that "talk" to the "mother ship" and connect the individual consumer continually to the information and monitoring centers run by the manufacturer or operator. In some production lines, this is also enabling the manufacture of small-batch, made-to-measure products at the same price as mass-produced ones. The field of logistics is also becoming increasingly intelligent, from product delivery to maintenance, and from customer service to postsales support. Supply chains are more and more interconnected and operate on just-in-time principles. Intelligent factories are also becoming a reality: online machines that "talk" to one another and combine the physical world of transforming materials with the virtual world of just-in-time information, automation, and digital monitoring. All of this can step up productivity and increase the flexibility of design and production.

Technological convergence is also creating a trend toward "distributed manufacturing," a new phase in the decentralization of manufacturing which reduces the importance of economies of scale in some areas of activity. This will also impact traditional hierarchies in the organization of production and firm size, creating new opportunities for small and medium-sized companies, which can now become "intelligent," geographically dispersed manufacturing networks that are competitive even though they are small. These are complex trends that are having multiple, multidimensional impacts on production paradigms and the world of work. Industry 4.0 is not science fiction for the future—it is already a fact of life and will increasingly transform the region's production systems.

27%

OF THE WORLD'S MIGRANT WORKERS ARE IN THE AMERICAS

The fourth group of impacts concerns the risk of greater inequality. Technology is one of the main drivers for the polarization of jobs and salaries. Highly skilled, "connected" workers tend to benefit from these changes while less skilled, "unconnected" workers tend to lose out. It becomes increasingly difficult to find middle-skill jobs with high wages—the norm is increasingly high skills and high wages. Economists have described these impacts as the emptying of the middle (Autor and Dorn, 2013) or "average is over" (Cowen, 2013), because, especially in developed countries, the share of middle-skill jobs has shrunk, while that of highly skilled jobs has increased. This is the essence of the effect known as "skill-biased technical change." This shift has massive implications for social mobility and the sustainability of the middle class. It also reveals just how important education and professional training are: in other words, investment in human capital is a key asset in the age of the knowledge economy.

Latin America and the Caribbean have earned the reputation of being the region in the world with the greatest income inequality. Using the Gini coefficient as a measure, in the mid-2000s, the region was 18% more unequal than Sub-Saharan Africa, 36% more unequal than East Asia and the Pacific, and 65% more unequal than high-income countries (López-Calva and Lustig, 2010). However, after increasing in the 1990s, inequality shrunk in Latin America and the Caribbean between 2000 and 2007. In general, the main factors that affect inequality include: elite domination of the state, imperfections in labor markets, unequal opportunities (in particular, access to good quality education), the balance of taxation and state transfers, the segmentation of the labor market, and discrimination against women and ethnic groups. In other words, the quality and quantity of the supply of education and vocational training and the relationship between this and demand (which is generally biased toward greater skills content due to technological progress),[2] is one of the six main factors that influence inequality, be it positively or negatively, depending on the specific characteristics of each factor.

For example, one of the most comprehensive studies of the reasons why inequality has come down in Latin America and the Caribbean concluded that, while in the 1990s the demand for skills outstripped supply, higher school enrolment rates in the 2000s mean that the skills supply came out ahead. In other words, in the race between skill-biased technical change and improving or scaling up education, the latter took the lead in the first decade of the 21st century (López-Calva and Lustig, 2010).

However, this good news about what was observed up to 2010 has not necessarily continued. The results of the latest Programme for International Student Assessment (PISA) study on the quality of the education system were not good in Latin America and the Caribbean. The quality of the education that low-income young people have access to is very different to that of their medium-high-income and high-income peers and their opportunities for entering higher education are also significantly lower. School dropout rates remain high among secondary school students and large gaps persist in vocational training systems, while apprenticeships are very underdeveloped (OECD, 2014). If the state wishes to continue evening out opportunities through education and professional training, these gaps and problems need to be vigorously addressed.[3]

Furthermore, evidence from the region shows that the impact of public spending via transfers is still neutral or even regressive from a distributive point of view, while tax systems also tend to be regressive. Tax redistribution rates are thus low, particularly in comparison with the redistribution via taxes and transfers seen in developed countries.

Finally, inequality in Latin America is also rooted in the heterogeneity of productivity patterns between sectors, economic activities, and territories. This suggests that inequality must be fought not only through a combination of tax policies, social transfers, and better education and professional training, but also that productive development policies have a key role to play in reducing the structural discrepancies in productivity between sectors and territories.

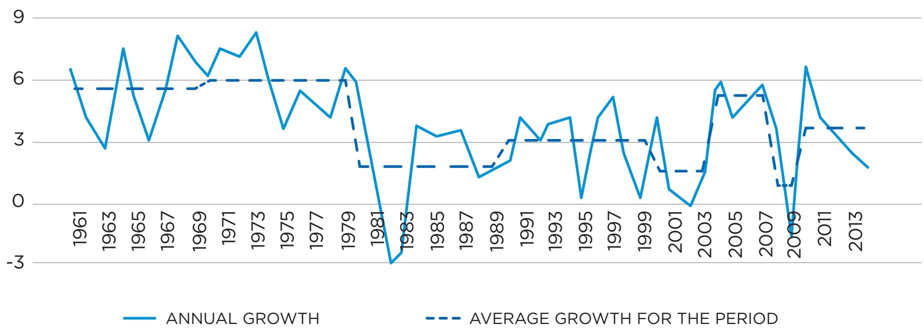
PRODUCTIVE DEVELOPMENT

In Latin America, 47% of workers are not formally employed, poverty rates remain at 29%, average productivity is half that of leading countries, the productivity gap is widening rather than narrowing, and the region is still highly dependent on commodity exports. Given this outlook, it is clear that a better future for work depends on countries implementing policies that promote productive development, innovation, and human talent to accelerate productivity growth and "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all," as UN Sustainable Development Goal 8 expresses. This goal is critical. Measured against the three criteria set out in Goal 8, it is fairly evident that growth in Latin America and the Caribbean is neither sustained, nor sufficiently inclusive, nor sustainable. Figure 2 shows the highly volatile growth pattern that characterizes the region.

With regard to inclusiveness, the data on informality, poverty, the gender gap, and the exclusion of indigenous communities, among other issues, reveal just how far the growth pattern is from generating greater equality and inclusion. For example, figure 3 shows how prevalent self-employment (28%) and work in micro-enterprises (also 28%) are in the structure of work in the region. Most of the informality and poverty in the region are concentrated in the 56% of workers who fall into these two categories. This employment structure, which is characterized by very few large and medium-sized firms, is putting the brakes on productivity growth. As the

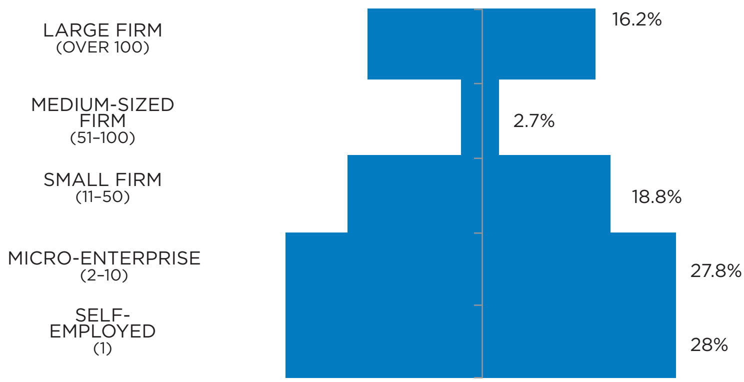
FIGURE 2
GROWTH VOLATILITY, 1961–2013

LAC: GROWTH RATES



Source: Compiled by the author based on data from ECLAC.

FIGURE 3
STRUCTURE OF EMPLOYMENT BY FIRM SIZE



Source: ILO (2015).

ILO (2015) report argues, more formal employment in large and medium-sized firms would help close the gaps in decent work.

It is true that the middle classes have increased in some countries, but recurring downturns or the "new normal" of mediocre growth are disappointing these classes' expectations of continual growth and upward social mobility, which complicates governability and politics and increases social conflict.

Furthermore, in needs to be understood that when inequality is extreme, it can undermine social cohesion and feed into feelings that "not all citizens are in the same boat." This is not just a matter of social policy but also of productive underdevelopment, because these inequalities are rooted in what ECLAC has been calling "structural heterogeneity" for decades. In other words, a highly heterogeneous growth and productivity profile in which a handful of sectors, activities, and territorial areas with high productivity rates and high wages coexist with a clear majority of sectors, activities, and territorial areas where productivity and wages are low. Governments and societies have been slow to understand that combating inequality is not merely a matter of social policies, but that it also entails productive development policies.

Fortunately, comprehension of this point is improving and there is now a return, although still a limited one, to policies to stimulate growth in productivity, accelerate the transformation of production patterns, invest in innovation, and develop human talent (Salazar-Xirinachs, Nübler and Kozul-Wright, 2014; Crespi, Fernández-Arias, and Stein, 2014; Cornick, 2016).

NEW BUSINESS MODELS

New technologies are prompting major innovations in business models. There is an explosion in a phenomenon that is being described in many ways: the "Gig economy," the "on-demand economy," and the "sharing economy" (Sundararajan, 2016). In jazz slang, a gig referred to an engagement to play music for one-off performances, a description that is not entirely inaccurate for what some online platforms or apps do, in that they are environments where temporary jobs are commonplace and organizations hire independent workers to provide services.

What lies ahead, and is already making a significant impact, is a radical shift from classic forms of employment (long-term relationships with a company that are regulated by a clear contract that lays out the conditions of employment and provides well-defined labor rights, including access to social security in the form of healthcare and pensions) to a variety of new forms of hiring such as freelancing and self-employment, temporary and part-time work, on-demand work, and a variety of forms of outsourcing (see ILO, 2016). For example, several studies predict that in 2020, between 30% and 40% of North American workers will be freelancers.

These new developments pose fundamental questions regarding how to regulate these new circumstances and how to guarantee all workers in this new world of work the basic protection afforded by classic labor rights.

One example illustrates these dilemmas. Omar, an Uber driver in Los Angeles, was attacked by a passenger and had to go to hospital. Omar asked Uber to pay his medical and hospital bills. But in the new sharing economy, workers do not have the classic protections associated with standard labor relationships (set working hours, unemployment benefit, a minimum wage, health insurance, and pensions). Situations like this have sparked intense legal debates and numerous lawsuits that revolve around the question of whether or not the workers for these new collaborative platforms have been erroneously classified as "freelance contractors" (Warren, 2016). Two options emerge in this debate: establishing a new category of "independent workers" and protecting them through special legislation, or recognizing that they are de facto employees and protecting them through existing legislation. This is a multifaceted issue, given the wide range of employment situations, and is one we are only just beginning to consider.

The risks and conditions of the sharing economy (low incomes and an absence of social security, health insurance, and pension coverage) apply not only to workers in this new economy but also to contract workers, part-time employees, and of course to the millions of informal workers in Latin America (who mainly work in retail trade and construction). So the challenge is not just regulating the "new sharing economy," but also guaranteeing basic protection for all workers.

This includes challenges such as how to expand coverage and make it easier for all workers to pay social security contributions and be insured against disability and illness; how to ensure that health and pension benefits pertain to the worker and are not linked to the employer; what financial and legal mechanisms could be established to connect these benefits to the worker throughout their working life regardless of their employment status (the portability of benefits); how to establish representation, freedom of association, and collective bargaining for workers in the shared economy; and how to ensure that workers can

advance their own interests. A variety of initiatives in this direction are already emerging in the United States and Europe. To bring together the voices of the nonorganized workers of the new sharing economy and ensure they are involved, the new rallying cry of 21st-century crowd-based capitalism seems to be "freelancers of the world, unite!"

POLITICAL VISIONS AND SOCIAL DIALOGUE

The penetration rates of technologies and the impact they are having; the possibility of there being accelerated, sustained, inclusive processes for learning, productive development, and transformation; and regulatory frameworks to cover new business models and new forms of hiring—none of these things are forces of nature that cannot be influenced. Social and political institutions, broadly understood, are what provide the incentives and opportunities for both economic and social innovation. As Acemoglu and Robinson (2012) argue, these institutions can be inclusive and work to benefit the majority; or they can be exclusive and extractive, favoring only a relatively small elite.

Whether the institutional circumstances of a given country lean in one direction or the other is strongly influenced by the political visions of the major social players and by the existence and quality of dialogue around public policies and public–private partnerships to achieve development objectives that integrate and define a society's governance mechanisms. In other words, the future of work should not be understood deterministically as the outcome of technological or other forces which societies have no control over. This future depends largely on societies' capacity for providing appropriate collective responses to impacts that can be anticipated and directing change in a positive direction and accelerating this process.

LABOR RIGHTS

In sum, the future of work in Latin America and the Caribbean depends not just on public policy responses but also on collective responses in several fundamental areas: (1) the demographic and migratory trends that lie ahead; (2) the impact of the technological revolution, which poses major questions regarding whether economies, societies, businesses, individuals, and educational and vocational training institutions are ready to take on new productive paradigms and accelerate learning at all levels; (3) national capacities for designing clear productive development and human talent policies to transform a growth model that remains highly dependent on commodities and where productivity levels are low; and (4) the drastic changes in business models and classic forms of employment toward a variety of new forms of hiring, which pose fundamental questions regarding how these new circumstances should be regulated and how we can ensure that all workers in this new world of work enjoy the basic protections provided by classic labor rights.

Timely and effective responses to the trends described here will only be possible under a shared vision forged through solid processes of social dialogue. We need new pacts that express this renewed, integrated vision of the nexus between productive development, technology, innovation, education, skills, jobs, and employability, on the one hand, and institutional reforms that translate into concrete action, on the other. This will require that we strengthen spaces and instances for policy dialogue, while also reviewing the logic of collective action and the institutions that support it.

NOTES

[1] The Economist, "Free Exchange. Why Taxing Robots Is Not a Good Idea. Bill Gates's Proposal Is Revealing about the Challenge Automation Poses," February 25, 2017.
[2] For more on skill-biased technical change, see Autor, Levy, and Murnane (2003) and Acemoglu and Autor (2011).
[3] For more on an agenda to improve skills and human talent for productive development and increased productivity in Latin American countries, see Salazar-Xirinachs, "Six Ways Latin America Can Close Its Skills Gap," World Economic Forum, May 7, 2015.

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CASE STUDY

DENMARK AND THE FIRST TECH AMBASSADOR

Big tech companies have bigger turnovers than many small and medium-sized countries. Microsoft's market value is on a par with Belgium's GDP, for example. Just 18 countries in the world have GDPs higher than the US$700 billion that Apple is worth. But their economic value aside, the information that these companies handle may pose a risk to national security or may help improve this. Their investments could bring about qualitative leaps in employment or accelerate knowledge transfers in major cities.

For all these reasons, Denmark has decided to create the world's first tech ambassador, who will be based in Silicon Valley. The first person to hold this position is Casper Klynge, former Danish ambassador to Indonesia. The driving force behind this pioneering idea is the Danish minister of foreign affairs, Anders Samuelsen. In this interview, he explains the new ambassador's mission.

Why did the government of Denmark decide to create a tech ambassador?

Tech and digitization need to be a foreign policy priority for at least two reasons. First, in Denmark we believe that we cannot approach technology and digitization as a black box. Second, Denmark has something to offer these countries. Denmark has taken great advantage of digitization. The European Commission's Digital Economy and Society Index recently ranked Denmark number one (which was also the case in 2016). In the language of diplomacy, this is "soft power." But there are also challenges ahead. For example, we need more IT specialists in our workforce.

What are the main issues that will be on this ambassador's agenda for bilateral relations? What kind of technology companies will he be interacting with?

The tech ambassador will spearhead a new "TechPlomacy" initiative, making tech and digitization a prior-

18

COUNTRIES IN THE WORLD HAVE A GDP HIGHER THAN APPLE'S NET WORTH

ity across Denmark's foreign service. One important task will be to establish relations with major tech players such as Google, Facebook, Apple, and Alibaba. He will also be connecting with start-ups and universities, civil society, NGOs, and cities and regions with valuable insight and experience in this field. Broad-based outreach to companies and civil society is nothing new. But we need to do more and we need a much more systematic focus on tech and digitization. In parallel, we will promote the tech agenda through "traditional" diplomacy vis-à-vis other nations and multilateral organizations.

How are states and citizens being affected by the growing importance of technology companies in the world?

Tech and digitization need to be foreign policy priorities and we cannot approach them as black boxes. Technological development and tech stakeholders have a huge influence on our society and affect a broad range of issues, including privacy, humanitarian aid, healthcare, job creation, infrastructure, and security, to mention just a few. The tech environment is one sphere of influence that will only become more important in the years to come. And it will do so on a massive scale.

Do you think that the growing market power of tech companies requires countries to respond as a group, at the European level, for example?

The EU and its institutions are important in this arena. We are certainly prioritizing this in EU discussions through initiatives like the digital internal market. But the EU is not the only arena. Tech and digital development affects all aspects of society, so we need to address some questions at the national level, some at the EU level, and some in other relevant fora and spheres of influence. That is precisely what this initiative is about. Engaging in new, vital spheres of influence that we as governments need to understand better, in order to then use this information appropriately.

ANALYSIS

The transportation of the future

If you don’t think about your future,
you won’t have one.

John Kenneth Galbraith

Alejandro Zamponi
INTAL/IDB

AUTONOMOUS TRANSPORTATION REDUCES COSTS BY TRANSPORTING FREIGHT ALONG DANGEROUS ROUTES WITHOUT PUTTING HUMAN LIVES AT RISK. DRONES, CARS, TRUCKS, AND TRAINS, AND NOW FREIGHT SHIPS AND PLANES ARE BEING AUTOMATED IN FULL OR IN PART. IT IS EXPECTED THAT ALL MANNER OF AUTONOMOUS VEHICLES WILL BE LEGALLY CIRCULATING AND BECOMING WIDESPREAD WITHIN A DECADE, WHICH POSES MANY QUESTIONS ON TRADE AND INTEGRATION REGULATIONS.

An executive is taking part in a videoconference for work. Next to the face of the person he is meeting with, on the windscreen of his vehicle, an automatic signal lets him know that he is about to reach his destination. The executive ends the meeting and gets out of the vehicle. He tries to close the door, but he can't: a warning message tells him that he has left his briefcase behind. This scene, which sounds like something out of a sci-fi novel, is something that we may still find surprising in the next 20 years, but it will be more or less normal in big cities all over the world by 2040, when more than 75% of vehicles will be autonomous (IEEE, 2012). Some 600,000 cars are expected to be autonomous by 2020 and 21 million by 2035 (Korosec, 2016). Other estimates indicate that the autonomous car market could represent US$42 billion by 2025 (Green, 2015). But cars are not the only vehicles that will be doing away with human drivers—this trend is affecting all forms of transportation. This article reviews the current state of affairs for each transportation type.

AUTONOMOUS AIRCRAFT

The remotely piloted drones that the United States uses to combat terrorism in the Middle East are well known, but there are others that fly pre-established routes to deliver medicines in Africa.

Autonomous aircraft could totally transform postal services as we know them. Amazon is already introducing changes to trade: from Amazon Lockers for delivering orders to automatic drones to deliver small shipments and which are already being used as part of the company's Prime Air service in cities in the United States, the United Kingdom, Austria, and Israel.

Amazon argues that, within a few years, delivery drones will be as commonplace as trucks. Meanwhile, their teams are evaluating the different environments in which their drones must operate and are examining alternatives, such as parachute-aided delivery.

BAE Systems has already started testing an autonomous version of a turboprop plane, the Jetstream 31, which is fitted with systems to adapt its routes to air traffic and weather. The plane uses satellite information on weather conditions and a traffic collision avoidance system (TCAS) to find out the position, flight path, and speed of other aircraft and calculate the probability of encountering them. It also carries cameras that allow it to detect other aircraft if these are not transmitting a TCAS signal.

BAE Systems is not the only company working on this type of project.

75%

OF THE WORLD'S VEHICLE FLEET WILL BE AUTONOMOUS BY 2040

Aeronautical firms from all around the world are investing resources in improving automatic pilot systems and including them in commercial and freight operations. The aim is not to eliminate one of the most stressful professions in the world, although they may end up doing so, but instead to bring down operating costs and reduce human error. The industry calculates that this type of aircraft will become widespread within a couple of decades at the most, starting with freight operations.

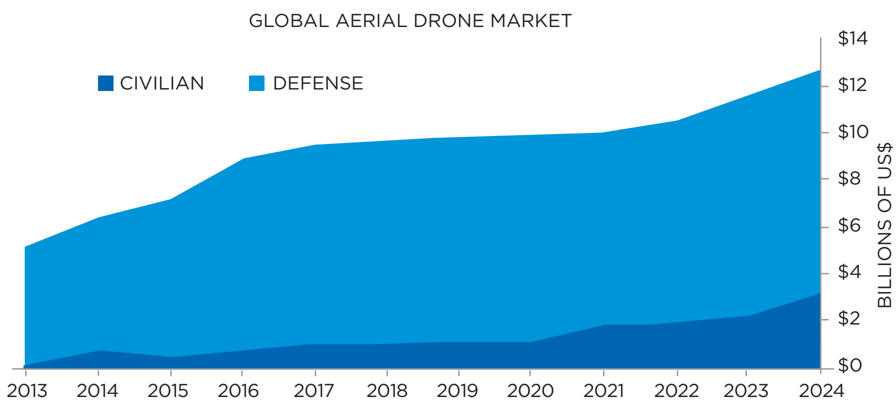
AUTONOMOUS SHIPS

Over 90% of global trade takes place using sea transportation. At the center of this are 50,000 merchant ships that transport all sorts of cargo between 150 countries and employ around a million sailors from practically every country in the world (International Maritime Organization, 2017).

Large shipping firms have become allies in the process of exporting goods from China, the so-called Asian Tiger economies, and the European Union. Together they move more than 800 million tonnes of freight, are more competitive than air transportation, and are less of a threat to the environment than fossil fuel-based land transportation.

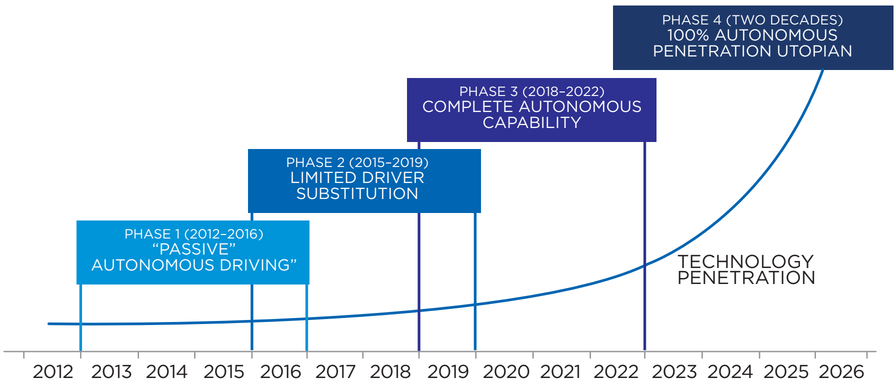
The size of freight ships increased by 1,000% between 1970 and 2014 (Container Transportation, 2016). Today's ships could be compared to skyscrapers lying on the surface of the sea: complex structures that demand ever more complex technology to en-

FIGURE 1
ESTIMATION OF THE AERIAL DRONE MARKET



Sources: Teal Group, BI Intelligence Updates, Michael Toscano.

FIGURE 2
ESTIMATED PENETRATION TIME FOR AUTONOMOUS CARS



Source: Company data, Morgan Stanley Research Division.

sure a safe passage. From augmented reality to artificial intelligence, all technological developments are seeking to contribute something to the control rooms of the future. It is just a matter of time until autonomous ships with no captain or crew start operating.

There are also plans for smaller ships, which would entail lower costs and better safety conditions for the goods and the human lives involved.

As well as cars, Rolls-Royce produces engineering solutions for propelling all types of vehicles. It is currently researching the possibilities of autonomous ships for maritime freight transportation, in partnership with other companies and universities, as part of the Advanced Autonomous Waterborne Applications (AAWA) Initiative. This project is financed by private companies and the Finnish government and has already built a 65-meter prototype equipped with sensors and commands that can be operated from thousands of kilometers away.

The real front runner, however, is the Pentagon: after investing US$120 million, it unveiled the largest autonomous ship ever built, the Sea Hunter. This 40-meter ship is equipped with radar and sonar systems, cameras, and global positioning systems and can travel 18,520 kilometers independently in search of submarines and naval mines. The Defense Advanced Research Projects Agency (DARPA) and the US Navy are investigating the Sea Hunter's ability to avoid hitting other ships along the San Diego coast.

Another parallel initiative, Roboat, seeks to develop autonomous fleets to transport people and goods while also controlling the onboard environment and installing temporary infrastructure, such as on-demand bridges. It is taking part in the US$28 million research project run by the Massachusetts Institute of Technology, the Amsterdam Institute for Advanced Metropolitan Solutions, Delft University of Technology, and Wageningen University, the latter three of which are based in the Netherlands. They will start to test the first prototypes on Amsterdam's canals in 2017 and will complete development within five years.

AUTONOMOUS CARS

Driverless cars

Autonomous cars are close to reaching the mass market. Major car companies are racing against one another and spin-off firms to offer the first partly or fully autonomous model. Ford, Google, Mercedes-Benz, Tesla, nuTonomy, and Uber are just some of the brands that have said in official press releases that their models will be on the streets of the United States before 2021 (Driverless Car Market Watch, 2017). So heated is this race that there are already six categories being used to describe the degree of autonomy that cars have, from level 0 (current cars) to 5 (fully autonomous).

Companies like BMW, Toyota, and General Motors are also investing in developing the car of the future, motivated by climate change and issues related to safety and quality of life: the average commuter spends hours stuck in traffic each week and spends a lot more driving. Furthermore, over 1 million people throughout the world die in traffic accidents each year, 94% of which are caused by human error (World Health Organization, 2013; NHTSA, 2017).

Flying cars

The first flying cars are expected to reach the market this year. Although there are several downsides to prototypes for the PAL-V One and Terrafugia's model (they cost as much as a small private plane and require a pilot's license and a runway for takeoff and landing), they are yet another sign of how the sector is booming.

Other firms developing prototypes include Airbus, AeroMobil, Volkswagen, Uber, Apple, and Zee.Aero, but it is only a question of time before we will no longer be able to count the companies involved in this market on the fingers of both hands.

94%

OF CAR ACCIDENTS ARE CAUSED BY HUMAN ERROR

As well as helping users to avoid traffic jams and enabling them to reach mountainous regions or deserts or places where infrastructure is limited, flying and autonomous cars have far-reaching impacts that demand new regulatory and institutional architecture. So thinks Juraj Vaculik, CEO of AeroMobil, who says that we need to reconfigure the laws that have governed air and land transportation the last hundred years.

In the meantime, the Ehang 184 drone, an autonomous aerial device with four rotor motors that can carry a person weighing up to 99 kg at 100 kilometers per hour, will start operating in Dubai in 2017.

Other companies developing personal aircraft include e-volo and myCopter. The latter is an EU initiative which sees flying cars as the transportation of the future for people living in big cities.

Trucks, Platoons, and Smart Roads

Platoons or intelligent road trains are sets of trucks that travel together using wireless coupling. The fleet automatically follows the pace set by the driver of the front vehicle.

The main benefit of this innovation is improved safety; wage savings, which account for 34% of total costs; fuel savings of up to 15%; and more road space, due to reduced headway between vehicles.

This technology for integrating territories more sustainably already exists. In 2016, the EU began to attempt to scale it up, at the behest of the Netherlands, as the port of Rotterdam has experience in receiving platoons of automatic trucks manufactured by DAF, Daimler, Iveco, MAN, Scania, and Volvo. This is part of the EU's quest to achieve its long-term Vision Zero target (zero accidents, zero emissions, and zero congestion).

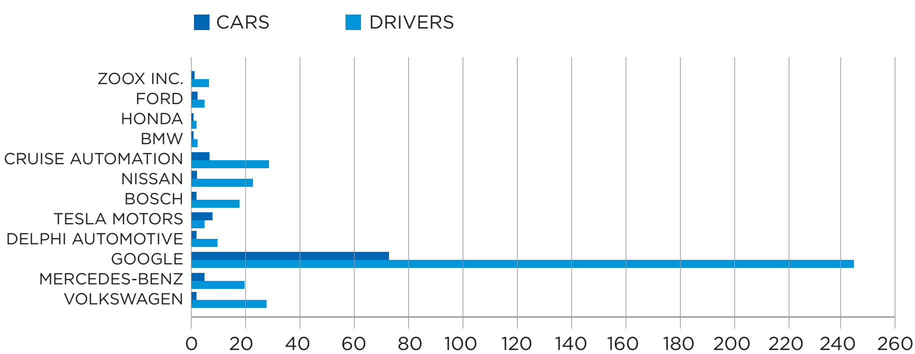
Daimler has already tested the first licensed autonomous truck. The Freightliner Inspiration Truck is a level 3 autonomous vehicle on the NHTSA scale, which is operated by the US agency that regulates road safety. This means that the driver can hand complete control over to the vehicle, although the autonomous functions will initially only consist of a driver support system to improve drowsiness and exhaustion levels by up to 25%. Daimler says that the vehicle has already traveled over 16,000 kilometers on closed circuits in Germany.

Meanwhile, Uber, whose autonomous cars are already operating on the streets of Pittsburgh, has gotten one of its autonomous trucks to deliver a beer shipment. The vehicle in question was a Volvo truck outfitted by the start-up Otto with hardware and software including two lane-detection cameras, a LIDAR for the 3D environment, two front radars to detect obstacles and other vehicles, and a GPS to determine the vehicle's location at all times. More than 80% of the 194-kilometer trip was made at an average speed of 89 kilometers per hour without the driver having to do anything but sit in the cabin for 160 kilometers of the trip. The vehicle was accompanied by a Colorado state patrol and monitored remotely from Otto headquarters.

Trains and Subways

Trains were one of the first forms of transportation to have the technology needed to dispense with drivers. The London Underground has had an autonomous line since 1967, the Victoria Line. The main benefits of such services are lower costs and more frequent ser-

FIGURE 3
COMPANIES WITH PERMISSION TO TEST DRIVERLESS CARS IN CALIFORNIA



Source: California Department of Motor Vehicles.

FLYING CARS AND THE HYPERLOOP

If flying cars become widespread, they will bring huge mobility advantages to places with limited infrastructure. But they also signify a threat to the jobs of millions of people who build and maintain highways, airports, and other transportation infrastructure.

Our societies cannot stop technological development, but they can slow it down. Indeed, they already are: technology does not advance faster because we do not allow it to. Millions of human lives are at stake, if not the future of humanity. We want more integration and more trade. Technology drives change and public institutions must adapt to it.

And as if electric and the flying cars were not futuristic enough, a new form of transportation is being developed which will reach supersonic speeds and link the world's main cities for the price of a subway fare. Hyperloop is an autonomous, on-demand transportation system that involves autonomous floating pods that are propelled at twice the speed of a commercial airliner along a vacuum-sealed tube using electric motors. It is expected to be operational by 2020.

vices.

Other cities with driverless train services include Copenhagen, Barcelona, Turin, Rennes, Milan, Rome, Brescia, Paris, Rennes, Toulouse, Lille, Lyon, Nuremberg, Budapest, Miami, Vancouver, São Paulo, Santiago de Chile, Lima, and Dubai.

Rüdiger Grube, former CEO of Deutsche Bahn, the largest railway company in Germany, attested to the benefits of this system when he claimed that the company would start operating autonomous trains on some sectors of its rail network in around 2023.

CONSEQUENCES FOR TRADE

Cars, helicopters, ships, planes, drones, and even new supersonic forms of transportation are all expected to become autonomous within 20 years. In fact, autonomous transportation is likely to spearhead the penetration of artificial intelligence (AI) in Latin America, bringing with it both positive and negative consequences.

Autonomous transportation means, on the one hand, that 13% of the economically active global population could lose their jobs (Kharpal, 2017). Adding 13 percentage points to any country's current unemployment rate gives a sense of the human drama this would unleash. In South America, it would mean 44 million new people losing their jobs by 2025. On the other hand, the flipside of this labor crisis would be that automation may bring equally polar advantages: operating costs and accidents would go down and there would be less need for humans to perform repetitive or physically grueling tasks, and so on.

Given this outlook, humanity's tech leaders are suggesting taxing robot owners. This is true of Bill Gates and Elon Musk, although the latter went one step further when he said that people will end up merging with machines to avoid becoming obsolete.

The current state of affairs is that, as of mid-February 2017, the European Parliament passed a resolution (with 396 votes in favor, 123 against, and 85 abstentions) urging the executive and legislative body for the EU, the European Commission, to draft a legislative proposal around nine laws set out in the document entitled *European Civil Laws Rules in Robotics* (Nevejans, 2016). These include the proposal for specific taxes to be levied on robots.

Although it is hard to foresee the exact timeframe and scale of this phenomenon, the indicators allow us to project future hypotheses regarding the types of occupations and tasks that are easiest to substitute. For example, jobs in transportation and logistics run a greater risk of being automated than jobs in education and finance, because tasks involving perception and handling or social and creative intelligence are the hardest and costliest to automate.

13%

OF GLOBAL JOBS RUN THE RISK OF BEING AUTOMATED

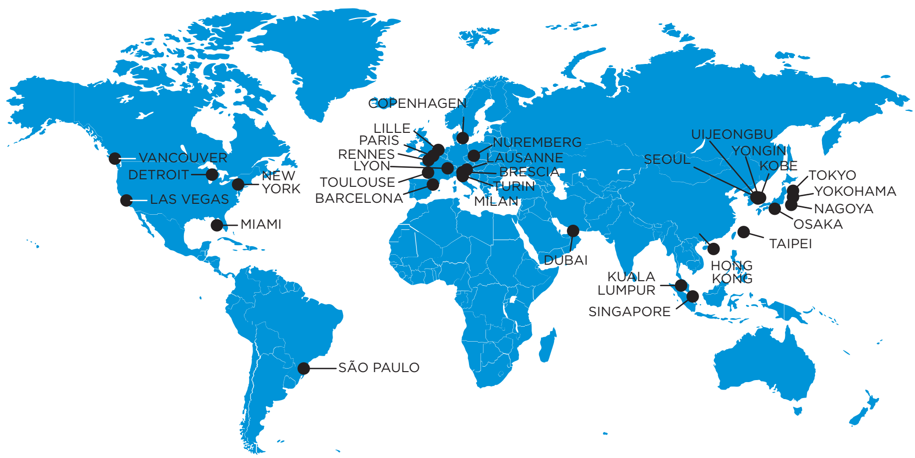
Automating human labor may eventually increase the amount of free time available to the population, which begs a series of new questions. What would happen at the individual level? What would societies do with so much free time and excess people? Some authors argue that we are witnessing the end of work and the rise of crowd-based capitalism. Social integration will no longer

THE POTENTIAL OF NEW MATERIALS

A The current performance of batteries is scandalously poor. Despite constant improvements in stability, cycles, and capacity, they are the bottleneck for all kinds of devices: from electric cars to cell phones and laptops. However, thousands of research groups are seeking alternatives that will end such limitations. When these researchers achieve their goals, not only will there be a boom in renewable energies, there will also be a leap in innovation. In this sense, one of the key strategies is developing new materials using nanotechnology, such as graphene, an electric superconductor that can withstand high temperatures, which allows it to store more energy and less space and drastically reduce storage times. Some cell phone models have already started to use this technology.

The inventor of the Li-ion rechargeable battery, John Goodenough, made headlines again recently after creating a new superbattery that used glass electrolyte and sodium electrodes, instead of lithium. According to Goodenough, “Cost, safety, energy density, charge and discharge rates, and life cycles are critical for battery-based cars to become widespread. We believe that our discovery solves many of the problems that are inherent to today’s batteries” (Xataka, 2017). Although there are no official dates, if this new development follows a similar path to the Li-ion batteries developed in the 1980s, it will take around 10 years to reach the market.

MAPA 1
CITIES WITH AUTOMATED SUBWAY LINES



Source: International Association of Public Transport.

be structured according to positions in the labor market, but rather by the capacity to exchange goods and services (Sundararajan, 2016). Others argue that the potential of new technologies tends to be overestimated (Pfeiffer and Suphan, 2015; Autor, Levy, and Murnane, 2003).

The recent past has shown that distances are becoming ever shorter and that ever-larger numbers of goods and people are circulating more frequently. It is easier to emphasize the technological changes to the transportation sector than the scale of the movements of goods and people that these generate (Barbero, 2017).

Containers, high-speed trains, hybrid vehicles, and other advances correlated with increases in population size, production, and consumption, the globalization of the economy and trade, the territorial expansion of cities, and the increase in the international movement and motorization of people. For example, world trade increased by 6% between 1980 and 2014, and airline passengers per passenger-kilometer have doubled since the start of the 21st century.

Automation, that is, the application of machines to replace human labor in industry and the service sector, is a process that began around 200 years ago with the loom and the steam engine. These sparked the Luddite movement and other forms of resistance (Hobsbawm, 1952).

Over the past four decades, information technologies, the development of artificial intelligence, and robots have given rise to a "polarization of labor": the jobs typically performed by medium-skilled personnel have fallen victim to automation. This phenomenon has been observed above all in five developed countries which concentrate nearly 75% of global industrial robotic

COSIPLAN AND FREIGHT TRANSPORTATION IN UNASUR

To date, the technologies for automating transportation have been created in developed countries. There are no significant initiatives in this area in South America, which could mean that the impacts of these technologies in the region could lag years or decades behind the developed world. But they could also follow the pattern of the mobile phone market, which has spread irrespective of countries' development levels.

If automation reaches the region in the next 20 years, countries will be up against the challenge of regulating the adoption of these new technologies through ad hoc legislation, as has started to happen within the EU. In this sense, it bodes well that the UNASUR's more active councils include one COSIPLAN, which focuses on infrastructure planning.

Freight transportation and logistics are fundamental for the region because a very high percentage of investment in integration infrastructure is mainly oriented toward shipping freight. The countries of South America agree that how well their logistics perform has a direct effect on competitiveness: when the impact is positive, this factor integrates domestic and international markets and allows countries to exploit their local comparative advantages and economies of scale. When it is not, it becomes yet another shortfall in the integration process that needs to be overcome. Transportation and infrastructure development policies have a notable effect on how well logistics perform. For the region's governments, this poses the challenge of establishing policies within a shared and integrated framework.

The logistics-related transportation infrastructure in the COSIPLAN Project Portfolio covers six subsectors: road, rail, river, sea, air, and border crossings. There are clear links between these areas and the automation trends that are covered in this article. It would, therefore, make sense for COSIPLAN to consider including content on these new technologies in future sessions of its online course on policy-making for freight transportation and logistics, which nearly 100 government officials from 14 countries in Latin America have already completed. This proposal is important because COSIPLAN is implementing its Network of Freight Logistics Experts (REXLOG) through this critical mass of trained officials. The aim of REXLOG is to continually advise COSIPLAN on its decisions and the shaping of public policies, plans, projects, and regional initiatives to promote the development of national and regional logistics systems by first consolidating national systems.

installations: Germany, Korea, China, Japan, and the United States.

Although industries that are partly operated by machines are already commonplace, the process seems to have accelerated sharply since the global financial crisis. Average sales of industrial robots grew at a compound annual rate of 17% between 2010 and 2014, in comparison with a 3% rate between 2004 and 2008. This is the backdrop for similar changes in terms of transportation: all forms, be they land-, air-, or sea-based, tend toward automation

(Citi GPS: Global Perspectives & Solutions, 2016).

But autonomy in transportation affects not only millions of jobs, costs, and road safety. The spread of these technologies is posing serious challenges to customs, immigration, and logistics systems. What will movements of people and goods, which are currently regulated through taxes on passports, look like? Will megalopolises grow upward and concentrate larger proportions of the population or will easier travel expand the suburbs?

People who travel abroad often take advantage of this opportunity to acquire cheaper goods: clothing, technology, beverages, and packaged food. If flying cars become mainstream, increasing numbers of people will be able to acquire such goods without needing to import them, meaning that freight transportation systems and customs regulations will have to adapt. It will be difficult to tax goods if, in addition to every kilometer of border, millions of square kilometers of airspace need to be patrolled. The same is true of immigration. If traveling hundreds of kilometers, communicating with people who speak different languages, and hiring services become increasingly accessible, what will happen to the concepts of migration and nationality or that of home, in the sense of something that is located in a specific physical location? Autonomous transportation undoubtedly poses new challenges to integration and trade, and the countries of Latin America need to be prepared for these.

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CASE STUDY

ROBOTIC SURGERY

STATE-OF-THE-ART HEALTHCARE

New technologies are bringing about a true revolution in healthcare and lengthening human life expectancy. Robotics, in particular, has opened up a new chapter in the history of surgery and is being used in ways that optimize the outcomes of medical interventions so that patients recover more quickly.

Robotic surgery is a minimally invasive procedure that allows surgeons to operate using four robotic arms. Each one holds miniature instruments that are introduced into the patient's body through tiny openings. By controlling the robot's movements in real time, surgeons can carry out complex operations with a high degree of precision.

At the forefront of such techniques is the Da Vinci system, which was originally designed by the company Intuitive Surgical to support minimally invasive bypass surgery. The platform then began to be used in other areas of medicine and is now in its fourth generation.

The device carries out completely independent movements once it has been programmed by a surgeon. Da Vinci is an ergonomic platform that places a computer interface and 3D vision system between the surgeon's eyes and hands and the tips of the micro-instruments. From the control terminal, the surgeon operates remotely in real time, directing the movements of the robot, whose four arms hold miniature surgical instruments.

Some clinics and hospitals in Latin America have already acquired the platform. Marcelo Orvieto, director of the Robotic Surgery Program at the Clínica Alemana in Santiago de Chile, says that the introduction of the Da Vinci platform has helped them carry out less invasive operations.

What are the main outcomes that have been achieved since you adopted the Da Vinci platform?

The main outcome has been an increase in the use of minimally invasive

98%

OF CANCER-RELATED SURGERY CAN BE ASSISTED BY ROBOTS

techniques and procedures that were formerly only carried out using open surgery. One example is prostate cancer surgery or radical prostatectomies. At the Clínica Alemana, four years into the Robotic Surgery Program, 98% of such operations are carried out with robotic assistance. Appropriately implementing new technologies undoubtedly involves challenges, but there is a learning curve. It is essential to ensure that the risks that come with that learning curve are not transferred to the patients that should benefit from the new technology. The Clínica Alemana's robotics program began in late 2012 and included the hiring of a urological surgeon who had more than 10 years' experience using this technology abroad. We thus minimized the initial risks that might come with lack of experience in using the machinery. We also started an ongoing training program to ensure that the use of this technology spread quickly to other surgeons in different fields. At our hospital, robotic surgery is currently used in adult and pediatric urology, gynecology, face and neck surgery, and general surgery.

How do you train surgeons to use robotic techniques?

To achieve optimal results using robotic surgery platforms, it is fundamental to implement a training plan that includes both the surgeons who will use the system and the health staff involved in handling the machinery. As these surgeons meet the goals of the training program, they are allowed to operate with increasing levels of autonomy.

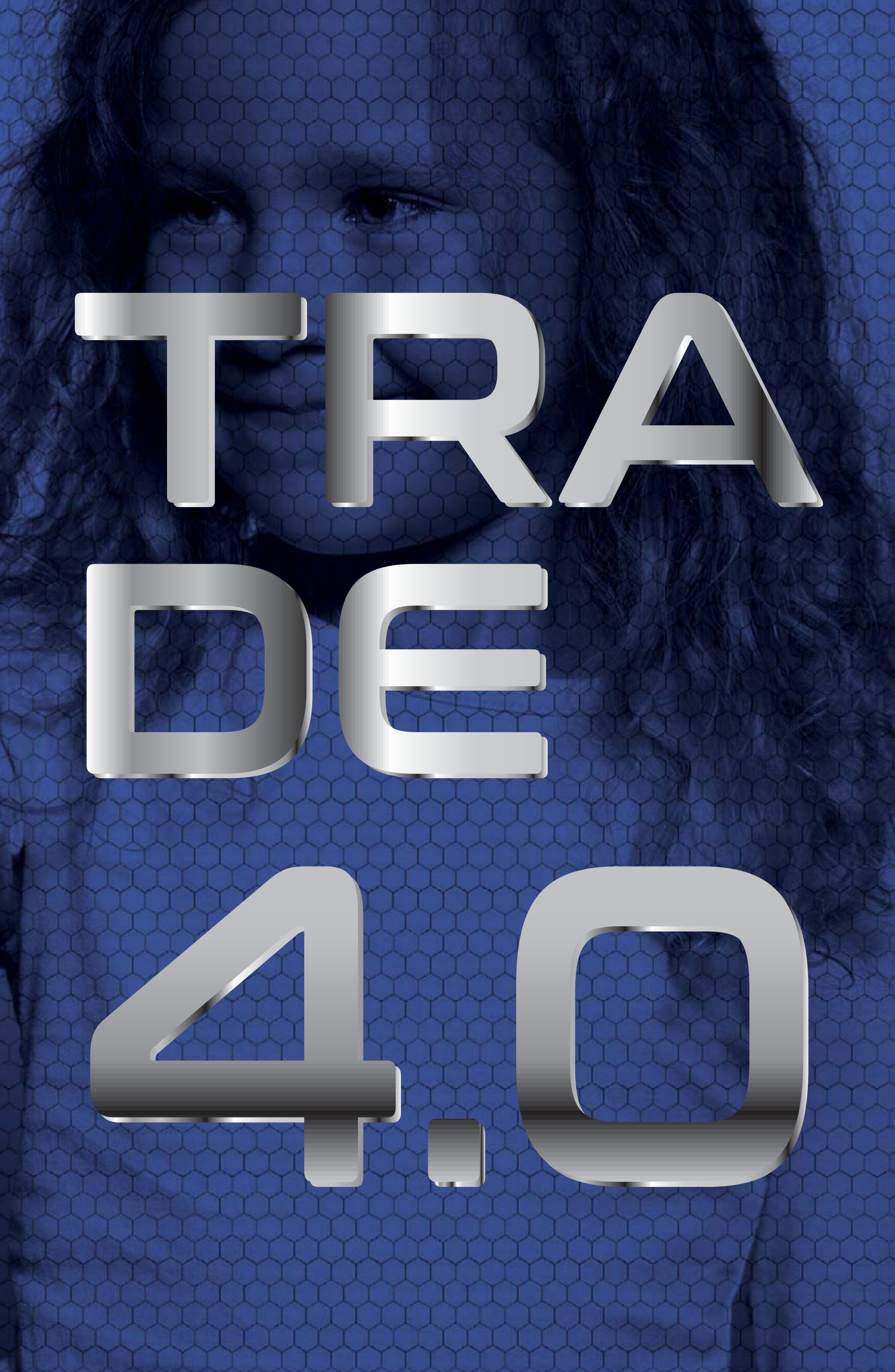
What are the advantages for patients?

Robotic surgery brings patients all the benefits of minimally invasive surgery: less bleeding and perioperative pain and better cosmesis, which translates into shorter recovery periods, meaning that they can resume their normal lives sooner. Once surgeons are sufficiently experienced, robotic surgery is advantageous when great precision is needed to preserve delicate tissues or carry out tiny movements in very small spaces, as is the case with pediatric urologic surgery, for example.

How is the use of robotic systems impacting employment in the healthcare sector?

The robotic systems that are currently being used are not automated, so they don't replace healthcare workers. Instead, robotic surgery is an interface between the patient and the surgeon, one that allows the surgeon to carry out extremely precise, delicate movements in areas that are hard to access.

One of the major challenges of the Fourth Industrial Revolution is how to bring the trade negotiations agenda up to speed with new technologies.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ANALYSIS

Andres Cadena, Susan Lund, Jacques Bughin, and James Manyika[1]

McKinsey Global Institute

The productivity leap

Your task is not to see the future
but to enable it.

Antoine de Saint-Exupéry

THIS STUDY ANALYZES THE IMPLICATIONS THAT NEW TECHNOLOGIES HAVE FOR PRODUCTIVITY AND EMPLOYMENT IN LATIN AMERICA. AMONG OTHER ISSUES, IT LOOKS AT HOW TECHNOLOGY MAY HELP TO REDUCE INFORMAL EMPLOYMENT AND THE CONSEQUENCES OF THIS REDUCTION FOR SOCIETY AS A WHOLE. IT ALSO EXAMINES HOW GOVERNMENTS AND FIRMS CAN TAKE BEST ADVANTAGE OF THEIR POTENTIAL TO ENSURE THEY REAP MAXIMUM BENEFITS FROM PRODUCTIVITY INCREASES WHILE TAKING ON THE CHALLENGES THAT THIS NEW TECHNOLOGICAL REVOLUTION IS POSING.

We are living on the cusp of a new automation era. Technologies including robotics, artificial intelligence, and machine learning are increasingly able to accomplish not just physical activities, but ones that include cognitive capabilities, from lipreading to driving. These technological advances, combined with increased digitization and the spread of data and analytics, are already supercharging the performance of global companies, and they hold the promise of boosting the productivity of national economies in countries around the world.

This paper draws on McKinsey Global Institute research related to Latin America's productivity and employment challenges and opportunities in an era of rapid technological change. It comprises four sections. The first focuses on long-running productivity issues in the region that will be exacerbated by demographic trends. The second section examines the extent to which digital and automation technologies could provide solutions to some of these productivity challenges, bolstering growth at a time of demographic change. The third section discusses the implications of these technologies for employment. Finally, we conclude with a discussion of the key labor market, social, and economic challenges that Latin American leaders will need to address to ensure the region can benefit fully from the productivity improvement that evolving technologies could enable.

CHALLENGES IN THE AGE OF ACCELERATION

Around the world, in countries from China to Germany and across Latin America, lower fertility rates and aging populations pose a considerable challenge to future economic growth. Over the past 50 years, the global economy expanded sixfold as the world's population and per capita income each grew at unprecedented speed. The global population more than doubled while average per capita income almost tripled to about US$13,000 at 2012 purchasing power parity. Two factors powered this exceptionally fast GDP growth: a rapidly expanding labor force and rising labor productivity. Each accounted for roughly half of global GDP growth. But the next 50 years look very different. The "demographic dividend" helping to fuel global growth in the past half century has come to an end, and the size of the working-age population is starting to decline in many countries. This fact will lower global GDP growth by 40% unless productivity growth accelerates to fill the gap. Boosting productivity will be essential if living standards are to continue rising.

PRODUCTIVITY LEAP

Latin America is no exception to this trend and indeed is likely to be particularly affected because its past GDP growth was due mainly to employment growth rather than productivity growth. Over the past 15 years, the region's average GDP growth has been about 3% per year, ahead of most advanced economies but lagging behind emerging ones. Growth across the region has been uneven. Bolivia, Colombia, Costa Rica, Cuba, the Dominican Republic Panama, and Peru have displayed the strongest GDP growth, with rates ranging from 4.2% to 6.5%, while growth in Mexico and Brazil—the largest economies—has been considerably lower, with cumulative growth rates of 2.7% and 2.2% respectively.

Regardless of the growth performance by country, the economies of the entire region display a similar trait: almost 80% of the total GDP growth has come from rising employment rather than increases in productivity, which represent the remaining 20% (The Conference Board, 2016) (figure 1).

Indeed, the increase in output per worker since 2010 in the region is just 0.4% per year, one of the lowest anywhere in the world (figure 2). Mexico, Argentina, and Brazil are the economies in the region where this phenomenon has been most marked, with employment contributing 80 to 90% of total GDP growth. That is considerably less than the average of the past 50 years in G19 countries plus Nigeria, where labor force growth accounted for 48% of the GDP growth in this period, while productivity growth accounted for the other 52% (McKinsey Global Institute, 2015a).

80%

OF THE REGION'S GROWTH WAS DUE TO AN INCREASE IN EMPLOYMENT

In the future, as elsewhere in the global economy, Latin America will no longer be able to rely on population and employment growth to fuel GDP growth as powerfully as in the past. Declining fertility rates will put an end to the cycle of employment-led growth, leaving productivity as the key to future growth and prosperity. Births per woman in the region have declined from more than 3.6 in 1985 to 2.1 today and are expected to decrease to just over 1.8 by 2030 (UN, 2015).

This decline in fertility rates will have dramatic implications for growth perspectives in the region. Employment growth by itself will only be able to generate 1.1%age points in terms of GDP growth over the next 15 years if no significant changes occur in the labor market. That is less than half of the contribution over the last 15 years.

This decline will have a disproportionate effect in the large economies of Brazil, Colombia, and Argentina, given the combination of high-dependency on employment growth and the large decline in fertility rates. We estimate growth in these countries could halve if no increase in productivity is observed over the next years and labor market conditions remain stable (The Conference Board, 2016; UN, 2015).

Under these conditions, an acceleration of productivity growth across the region will be essential to meet the growth aspirations of Latin America's people. An embrace of digital technologies and automation could help offset the economic growth gap that will open up in the region as a result of the changing demographical situation. How big could that technological bounce be, and how soon could it come?

HOW TO IMPROVE PRODUCTIVITY

Rapid technological advances in information technology, the Internet, and data and analytics capabilities have been fundamentally reshaping the corporate landscape in recent years, although adoption has been uneven among companies, sectors, and economies. Companies with advanced digital capabilities have increased their growth and market shares, improved their profit margins by three times faster the average and, more often than not, have been the fastest innovators and the disruptors in their sectors and outside them. These are the firms operating on the digital frontier, the first to adopt cutting-edge applications and expand the boundaries of how they are used.

There are disparities both within and among sectors. In the United States, the information and communications technology (ICT) sector, media, financial services, and professional services are surging ahead, while utilities, mining, and manufacturing, among others, are in the early stages of digitizing. This unevenness is also to be found across countries. The US economy as a whole is only reaching 18% of its digital potential, but still ahead of European countries, where the average is 12%. Latin America is further behind still, with countries in the region capturing less than 10% of their digital potential.

A new technological frontier now looms: automation. Some companies are already beginning to deploy advanced robotics and artificial intelligence technologies, while many more remain in the beta or testing stage. For example, Amazon is starting to deliver packages by drone and has unveiled a grocery store with no cashiers or checkout, while UPS uses artificial intelligence to optimize its route planning. Facebook's facial recognition software can now compare two photos and say with 97% accuracy whether they are the same person.

These advances are a result of large strides forward in robotics and artificial intelligence. Physical robots have been around for a long time in manufacturing, but now we are seeing more flexible, safer, and less expensive robots engaging in service activities—and improving over time as they are trained by their human coworkers on the shop floor. AI is starting to encroach on cognitive activities that were previously assumed to re-

quire human judgment and experience. For example, Google's DeepMind and the University of Oxford applied deep learning to a huge data set of BBC programs in 2016 to create a lipreading system that is more accurate than a professional lip reader.

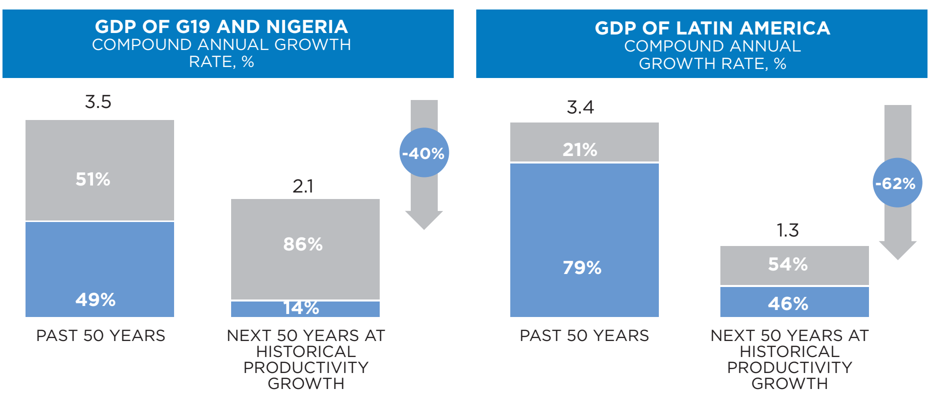
The technical advances in robotics and AI presage a significant increase in automation in coming years, on a global basis. Overall, we estimate that about half of the activities that people are paid almost US$15 trillion to do in the global economy have the potential to be automated by adapting currently demonstrated technology. All sectors will be touched. In the seven Latin American countries we studied—Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Peru—this potential would be associated with more than 75 million full-time equivalents and wages totaling almost US$1 trillion (McKinsey Global Institute, 2017a). Activities that are highly susceptible to automation include predictable physical activities--especially prevalent in key areas of Latin American economic activity such as manufacturing, retail trade, mining, and agriculture—as well as collecting and processing data, which are activities that exist across the entire spectrum of sectors, skills, and wages.

6%

THE AMOUNT OF ITS DIGITAL POTENTIAL THAT LATIN AMERICA MAKES USE OF

While automation may have serious implications for employment, it also has the potential to boost productivity growth and compensate for the demographic changes we highlighted in the first section. Overall, we estimate automation could give a productivity lift to the global economy amounting to between 0.8% and 1.4% of global GDP annually, assuming that human labor replaced by automation would rejoin the workforce and be as productive as it was in 2014.

FIGURE 1
GLOBAL AGEING WILL SLOW GDP GROWTH OVER THE NEXT 50 YEARS, WITH A DISPROPORTIONATE EFFECT ON LATIN AMERICA



Source: UN World Population Prospects, Oxford Economics, ILO, McKinsey Global Institute.

The productivity growth enabled by automation will have different implications for different regions and countries depending on their demographic situation and growth aspirations. For Argentina and Brazil, which face economic growth gaps as a result of the projected decline or slowing growth of their working-age population, automation can provide the productivity injection needed just to maintain current GDP per capita. However, to achieve a faster growth trajectory that is more commensurate with their developmental aspirations, these countries would need to supplement automation with additional sources of productivity, such as process transformations, and would benefit from more rapid adoption of automation. In the case of Mexico, which has a younger population, additional productivity-raising measures will be even more necessary to sustain economic development, alongside automation. However, automation will give a helpful bounce.

Exhibit 3 highlights our scenario for Brazil, which is quite representative of the situation in Latin America. It highlights the economic growth gap caused by demographic trends, and what would need to happen for Brazil to either maintain its current lackluster GDP per capita, or increase its GDP to a level in line with its aspirations for development.

Just because the technical potential to automate a workplace exists does not mean that deployment will happen anytime soon. Other factors, including hardware and software solution costs, labor market dynamics, and social and regulatory acceptance, all influence the pace and extent of technology adoption, which can be highly uneven. In economies in Latin America, for example, the relatively low wage levels and labor market issues we discuss in the next segment may mean it will take longer in some sectors to make a business case for automation than in some advanced economies where wages are higher and employment conditions more conducive.

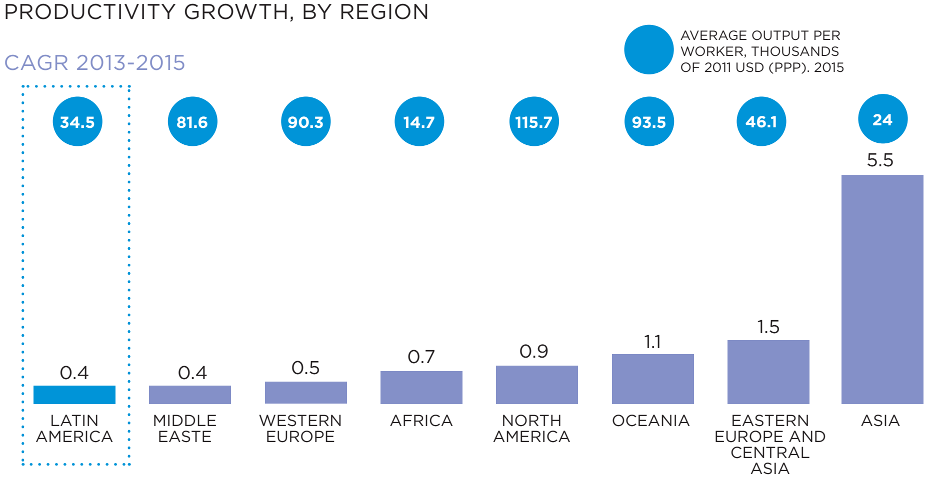
TECHNOLOGY AND THE LABOR MARKET

What will automation mean for employment and the future of work? This is a common question—and cause of anxiety—about technological innovation that dates back at least 200 years, since "Luddite" textile workers in Nottingham, England, smashed the automated looms deployed in their mills in 1811. In 1858, Karl Marx warned darkly that machinery was emerging as the new means of labor. In 1933, John Maynard Keynes described "a new disease" – the rapid pace of innovation outstripping the speed with which new jobs can be created.

History has shown that these fears were largely unfounded. While technological innovation has caused labor dislocation and sometimes difficult adjustments, in the long term it has created many more jobs than it has destroyed. In economies around the world, technological-driven productivity growth has been accompanied by employment growth (although often in different sectors of the economy).

It is still unclear whether the coming wave of automation driven by robotics and AI will be of a similar scale to technological advances in the past or whether it will cause more dislocation. The technology-enabled shift out of agriculture in developed countries in the 20th century prompted a massive transformation of the workforce. In the United States, for example, agricultural employment went from about 40% of US labor to less than 5% in about 70 years. Those shifts were accompanied

FIGURE 2
PRODUCTIVITY GROWTH IN LATIN AMERICA OVER THE PAST FIVE YEARS HAS BEEN WEAK IN COMPARISON WITH OTHER REGIONS
PRODUCTIVITY GROWTH, BY REGION



Source: Conference Total Economy Database 2016, McKinsey Global Institute.

by the creation of new types of work not foreseen at the time. In recent years, new occupations, such as app developers or MRI technicians, have replaced obsolete ones like switchboard operators. Could things be different this time, as we enter a new era of automation?

Overall, we find that less than 5% of all occupations can be automated entirely using today's automation technologies. (In our research, we focus on individual activities rather than entire occupations, because every occupation consists of a range of activities that have different requirements for automation.) However, almost all occupations will change: about 30% of the activities in 60% of all occupations could be automated (Exhibit 4). This will affect everyone from welders to landscape gardeners, mortgage brokers, and CEOs. We estimate about 25% of their time is currently spent on activities that machines could do, such as analyzing reports and data to inform decisions, or reviewing status reports.

As processes are transformed by the automation of individual activities, we thus need to think more about mass redeployment of labor rather than unemployment, including the skills that will be needed for the workforce of tomorrow. These skills will include a much closer interaction between humans and machines in the workplace. Some forms of automation will be skill-biased, tending to raise the productivity of high-skill workers even as they reduce the demand for lower-skill and routine-intensive occupations, such as filing clerks or assembly-line workers. Other automation has disproportionately affected middle-skill workers. As technology development make the activities of both low-skill and high-skill workers more susceptible to automation, these polarization effects could be reduced (Autor and Dorn, 2013).

Technology can also offer solutions to labor markets. This is perhaps most evident in the emergence of powerful online labor market platforms, which are improving the matching of jobs and people with the required skills. Such platforms are on the rise globally, including in Latin America. Consider that 60 million people across the region have profiles on LinkedIn, creating more transparency and detail on their experience and skills for potential employers. Indeed, Monster.com and other similar websites match individuals with jobs.

New online platforms in the "gig economy" or "sharing economy" are giving rise to new ways of working. Uber, TaskRabbit, UpWork, Etsy, eBay, and Airbnb are examples of platforms that connect buyers and sellers, creating new markets for labor in the process. MGI research finds that 20% to 30% of the working-age population in the United States and the European Union is engaged in independent work outside of a traditional employer-employee relationship (McKinsey Global Institute, 2016b). Just over half of these individuals use independent work to supplement their income, and also have traditional jobs, or are students, retirees, or caregivers. Independent workers who use digital platforms to find customers are more likely to use independent work as their primary source of household income. Moreover, independent work appears to be welfare enhancing: 70% choose this type of work as their preferred way of earning a living, and they report higher levels of satisfaction on 12 out of 14 different metrics of work-life, including not only flexible hours and control over working, but also income security. Although such platforms are small today, their rapid growth could enable a fundamental transformation of labor markets in the digital age.

Online labor market platforms have the potential to create transparency and efficiency in labor markets and potentially raise GDP. They can raise labor participation and working hours; evidence from around the world suggests that some people would work more hours if they could. With their powerful search capabilities and sophisticated screening algorithms, online talent platforms can also speed the hiring process and cut the time individuals spend searching between jobs, reducing unemployment. By aggregating data on candidates and job openings across entire countries or regions, they may address some geographic mismatches and enable matches that otherwise would not have come about. Finally, online talent platforms help put the right people in the right jobs, thereby increasing their productivity along with their job satisfaction. They can draw people who are engaged in informal work into formal employment, especially in emerging economies. We estimate that such platforms could raise global GDP by nearly 3% over the next 10 years, and improve the labor market outcomes for 540 million people around the world (McKinsey Global Institute, 2015b).

AN OPPORTUNITY FOR THE REGION

Capturing the opportunity created from greater digitization and automation, and from digital platforms that can transform labor markets, will require overcoming several barriers in Latin America. These include:

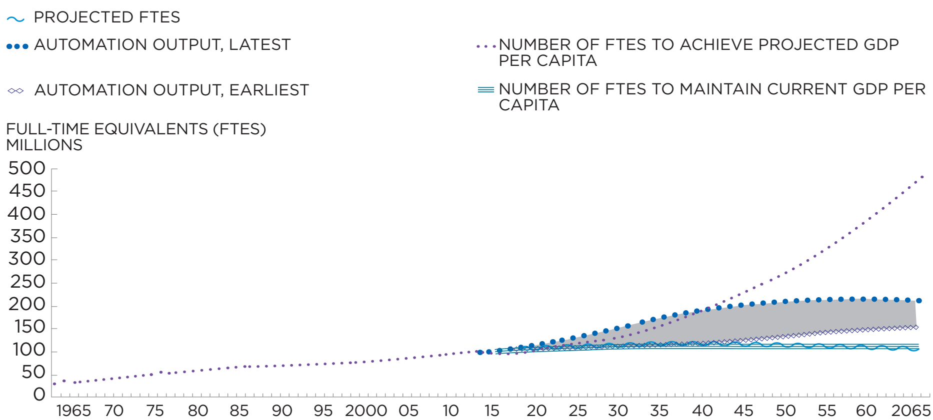
The large informal economy may be slow to digitize. The size of the informal economy in Latin America could act as a brake on technology adoption across the region. The International Labour Organization estimates that informal employment affects around 130 million workers in Latin America and the Caribbean, of whom at least 27 million are young people, and represents nearly half of nonagricultural employment.

Its incidence varies across the region's countries (from 30% in Costa Rica to more than 70% in Guatemala. Six out of ten jobs available to young people in the region are in the informal economy. In general, these jobs are of poor quality, low productivity and offer low wages (ILO, 2012, 2015). Informality also poses a major obstacle for adopting innovation and increasing productivity in general. The powerful incentives and dynamics that tie companies to the gray economy keep them subscale and unproductive, while the cost advantages of avoiding taxes and regulations help informal companies take market share from bigger, more productive formal competitors.

Harnessing digital technology could help raise tax compliance and reduce informality. The widespread use of mobile phones offers a cheap, convenient channel for both individuals and businesses to use digital payments. And digital payments, unlike cash, leave a trail that can be monitored. Using big data analytics to improve detection of tax evasion, governments have powerful new tools to dramatically improve compliance with taxes and other regulations and formalize the informal economy (see Lund, White, and Lamb, 2017).

A new emphasis will be needed to improve skills. A skills gap is a binding constraint for businesses in Latin America and poses a significant challenge for young graduates looking for jobs. More than half of 15-year-olds in the region do not acquire basic level competencies required by the labor market (IDB and CIMA, 2016). Access and quality present dramatic gaps compared to developed economies. Educational enrollment rates remain low, with only 74% of

FIGURE 3
AUTOMATION AND PROSPECTS FOR GROWTH FOR BRAZIL



Note: The "projected GDP per capita" scenario for Brazil uses projections from McKinsey's Global Growth model, with GDP compound annual growth rate (CAGR) for 2015–65 of 3.3%, resulting in a productivity CAGR of 3.2%. The "maintain current GDP per capita" scenario assumes GDP will grow at the same rate as population (0.2% CAGR for 2015–65), resulting in a productivity CAGR of 0.1%.
Source: The Conference Board Total Economy database; International Labour Organisation; United Nations Population Division; McKinsey Global Institute.

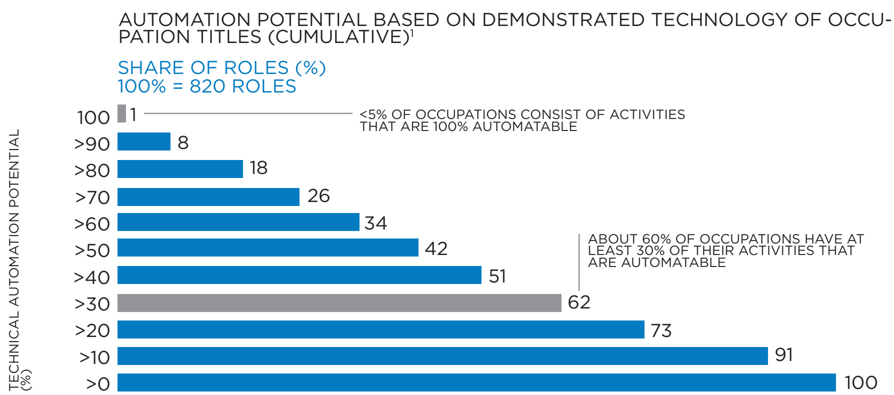
students enrolled in secondary education compared with 91% on average in OECD countries. In international tests, Latin Americans also underperform, with fewer than 2% of students ranking as top performers in mathematics, for example, as compared to 13% in OECD countries. Latin American countries will need to build stronger skill-based education systems, while implementing targeted interventions aimed at strengthening access and quality of education. Skill-based policies will also need to focus on demand side issues strengthening the linkages between education and labor markets.

Female participation in the workforce is relatively low. Latin America is missing out on considerable production capacity because of the relatively low participation of women in the workforce. The female participation rate is about two-third that of men, considerably below North America, Western and Eastern Europe and also behind China, East and Southeast Asia (McKinsey Global Institute, 2015c). Some countries are making faster progress toward gender equality than others, however: ILO data suggests that Chile is closing the gender gap in labor-force participation, and Ecuador is pulling women out of agriculture faster than other countries. If Latin America is to close the economic growth gap that is opening up because of demographic change, it will need all the workforce participation it can muster to ensure future prosperity, even in a new automation age.

Investment and innovation will need to be encouraged. Latin American countries lag behind innovation performance not only in comparison to developed countries but also in relation to emerging economies in other regions. For example, the region invests about 0.8% of GDP on research and development activities, compared with about 2.4% of GDP in OECD countries, or 1.8% in China (World Bank, 2017). Access to capital is one binding constraint for adopting innovation. The inability to access credit and the high cost of credit are major obstacles for the growth of

FIGURE 4

WHILE FEW OCCUPATIONS ARE FULLY AUTOMATABLE, 60% OF ALL OCCUPATIONS HAVE AT LEAST 30% TECHNICALLY AUTOMATABLE ACTIVITIES



Note: 1. We define automation potential according to the work activities that can be automated by adapting currently demonstrated technology. Based on US data.
Source: US Bureau of Labor Statistics; McKinsey Global Institute.

the mid-sized businesses that can create new jobs and innovate. Government and the private sector—banks as well as large corporations—can help. Financial reforms should include strengthening support for creditors to encourage lending, such as by improving the process for recovering collateral. The government can push for improvements in credit reporting, too. Banks can help by going back to "growing" their business customers—starting with small loans and staying with the same clients as they prosper and need additional services. Banks can also modernize their credit-granting processes, using data analytics and new unconventional forms of information that can be used to gauge creditworthiness. Large companies with access to low-cost capital can help finance smaller partners directly, by offering financing for equipment or technology purchases, for example. There is room for innovative solutions to boost lending and close the credit gap, such as Alibaba has done in China. Financial inclusion remains a priority, as 48% of Latin Americans remain excluded from access to financial services. Digital financial services have the potential boost GDP by 5%–6% in the long term in economies like Mexico and Brazil through increased productivity, increased investment, and increased labor.

Breakthrough advances in technology and the increased adoption of digitization and data analytics mark an inflection point for the global economy that is of especial relevance and importance for Latin American countries. The region's demographic trends mean that the era of employment and population-driven growth has ended. A new productivity imperative looms if countries across the region are to attain the longer-term growth to which their populations aspire, and on which their societal development will largely depend. Adoption of technologies, especially ones that will usher in a new automation era in the region, is complex from an operational perspective and raises difficult questions about employment and skills that governments and business will need to answer. Yet Latin America has a major interest in embracing the opportunities and the growth potential these technologies offer, as a way to ensure future prosperity.

NOTES

[1] The authors express appreciation to many colleagues whose work contributed to this paper, including Jacques Bughin, Michael Chui, Sree Ramaswamy, and Jaana Remes.

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ANALYSIS

Compet and global value chains

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University of Groningen

itiveness

> We should try to be the parents of our future rather than the children of our past.
>
> Miguel de Unamuno

LOS TRADITIONALLY, RESEARCHERS EXAMINE THE COMPETITIVENESS OF INDUSTRIES AND COUNTRIES USING EXPORT SHARES. THIS MEASURE HAS BEEN MADE OBSOLETE BY THE INCREASED INTERNATIONAL FRAGMENTATION OF PRODUCTION AND THE EMERGENCE OF GLOBAL VALUE CHAINS IN RECENT DECADES. THIS ARTICLE PRESENTS A NEW MEASURE OF COMPETITIVENESS THAT EXAMINES THE INCOME GENERATED IN BRAZIL AND MEXICO FROM UNDERTAKING ACTIVITIES IN GLOBAL VALUE CHAINS. THIS PROVIDES POLICYMAKERS A BETTER TOOL FOR EFFECTIVE INDUSTRIAL POLICY.

In the 21st century, the different stages of production no longer take place in a single country. This has wide-ranging consequences on how a country's competitiveness should be analyzed. An excellent example is the production of iPhones in a factory near São Paulo, where some of Apple's iPhones are produced and exported. This involves mainly assembly activities, whereas high-value activities such as development, design, and marketing of the iPhones are tightly controlled by Apple. In addition, the fabrication of many components, such as the processor and the touch screen, is done elsewhere in the world.

Companies such as Apple view production processes as a bundle of activities. Because of better information and communication, technologies activities are increasingly undertaken in the location with the best price-quality ratio. Therefore, activities are sometimes done at great physical distance from each other. Global value chains developed at an extraordinary pace in recent decades, primarily because of socioeconomic developments in Asia and Eastern Europe (Baldwin, 2006; Timmer et al., 2014). Therefore, analyses of competitiveness based on export shares are no longer adequate as this approach is only meaningful if all activities needed for making a product take place within national borders. It now urgently needs to be revised.

International trade statistics show which goods and services a country exports, but they do not show the value that is added in Brazil to the iPhone, for example. Statistical offices have long distinguished between three types of export flows, namely, transit (export of products that have been previously imported without a change in ownership), re-exports (exports of products that did change ownership but which have been left largely untouched), and exports (products produced in the country). Implicitly, this distinction captures the idea that the value that is added inside the country is small in the case of transit and re-exports, and large in the case of exports.

This distinction in export flows is certainly useful, but it is not sufficient: the exported iPhones add much less to Brazil's GDP if only assembly activities take place as compared to if Brazil also produced valuable touch screens and processors or designed new models and undertook marketing activities. As a consequence, policymakers are misinformed, because the competitiveness of a country lies in certain activities and not necessarily in products or sectors,

20%

THE SHARE OF PROFESSIONALS IN MEXICO'S REVENUE

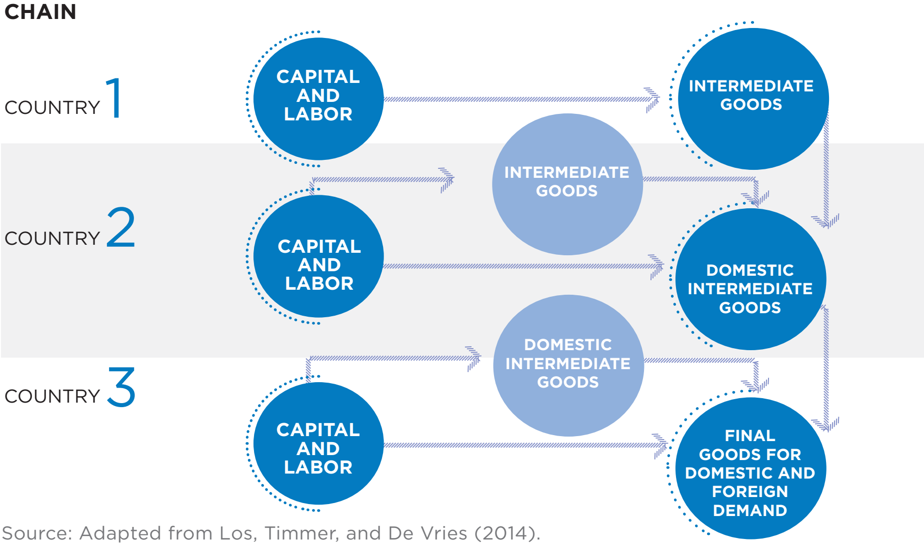
so they are not able to create effective trade and industrial policies. It is no longer about what you export, but what you do in global value chains.

To measure the value that is added to exports, the entire production chain needs to be mapped. This article sketches out a new method to determine comparative advantage based on an analysis of Brazil and Mexico's value-adding activities in global value chains. The need for such analysis has already been recognized. The availability of new data on the trade relations between countries and new methods means that undertaking this type of analysis is now a possibility.

FRAGMENTED GLOBALIZATION

We wish to study the production fragmentation of final products. A final product is consumed, in contrast to intermediate products, which continue in the production process. Consumption is broadly defined as including private and public consumption, as well as investment. A global value chain of a final product is defined as the value added of all activities that are directly and indirectly needed to produce it. This global value chain is identified by the country-industry where the last stage of production takes place before delivery to the final user.

FIGURE 1
STYLIZED REPRESENTATION OF AN INTERNATIONALLY FRAGMENTED VALUE CHAIN



Source: Adapted from Los, Timmer, and De Vries (2014).

Figure 1 sketches out a simple example of the production process for a final product, which involves three countries. The final product, say a car or a smartphone, is made in country 3. To produce this final product, primary production factors are needed, along with domestically produced intermediate inputs, such as components, materials, and business services. In addition, some intermediate inputs are imported from country 2. Country 2 adds value by producing these intermediate inputs. This added value may come from the industry that produces the intermediate input (a so-called first-tier supplier), but may also originate in other sectors of country 2 that supply material and components for the activities of the first-tier supplier (so-called second-tier suppliers). Finally, in this example, there are also second-tier suppliers in country 1 that add value.

To determine the value a country adds to the production of a final product, we have used world input-output tables (see box 1). These tables describe the domestic and international deliveries of goods and services by industries to other industries. Using these tables and an input-output method, the value that is added in each country to the global value chain of a particular final product can be calculated. This method was introduced more than half a century ago by Nobel prize winner Wassily Leontief (see Miller and Blair, 2009, for an overview of input-output methods).

4%

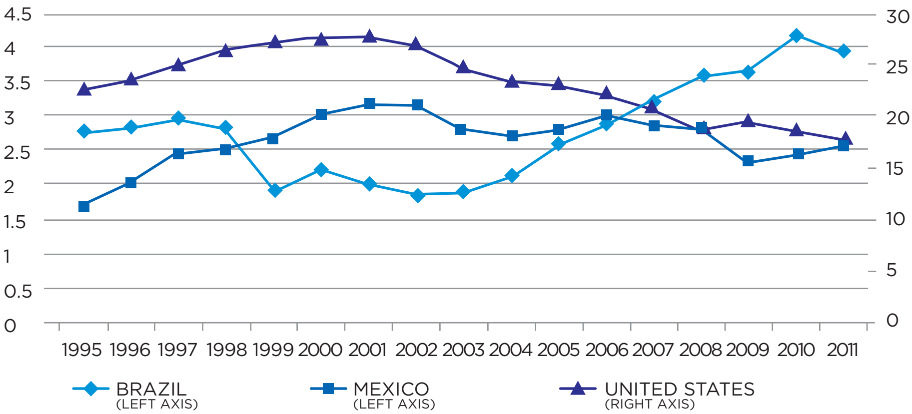
BRAZIL'S CONTRIBUTION TO GLOBAL VALUE CHAINS

The value added of a final product has rapidly fragmented across countries during recent decades. This is due to regional fragmentation by countries in trade blocs (such as NAFTA and the EU) and fragmentation by countries that are part of different trade blocs (Los, Timmer, and De Vries, 2014). Obviously, these value chains do not only include activities performed by manufacturing industries, but also other those of sectors such as agriculture, utilities, and financial and business services. These indirect contributions are substantial.

THE CONTRIBUTION OF BRAZIL AND MEXICO TO GLOBAL VALUE CHAINS

Figure 2 shows the value-added shares of Brazil, Mexico, and the United States in the global production of manufactured goods between 1995 and 2011. The total value of these goods has increased rapidly in recent decades, primarily because of increased consumption in emerging markets. China's share has risen sharply, particularly since it joined the WTO in 2001 (Timmer et al., 2014). This has been at the expense of traditional industrial strongholds such as the United States and Germany. This may seem surprising at first sight, given the export miracle that has taken place in Germany. Note, however, that a largeex part of this miracle can be traced back to the offshoring of activities to Eastern Europe. Hence, exports remained high, but the share of value that was added in Germany declined (Marin, 2011; Timmer et al., 2013). This underscores the need for a fresh look at competitiveness. It is, however, important to note that the analysis in this article is based on the location where value in

FIGURE 2
VALUE ADDED SHARE IN THE PRODUCTION OF MANUFACTURED GOODS (IN PERCENTAGES)



Source: World Input-Output Database (WIOD)

global value chains is added, not who enjoys the income. Germany, for example, has a considerable ownership share in the value added in Eastern Europe. A rough calculation suggests that this does not have a major influence on the results (Timmer et al., 2013).

The share that Brazil adds to value added rose from 2.8% in 1995 to 4% in 2011, increasing in particular after 2003. For Mexico, the share rose from 1.7% to 2.6%. Most of these increases took place in the 1990s and then declined slightly in the 2000s. Given the substantial changes that have taken place in the organization of global value chains, whereby activities are relocated to those countries where goods can be produced at lowest costs, one expects a shift in the type of activities through which Brazil and Mexico contribute.

THE ROLE OF SPECIALIZATION

To determine the activities that Brazil and Mexico undertake in manufactures global value chains, we have used occupations data. Workers are classified depending on their main activity, following the pathbreaking research by Michael Porter (1985). Six activity groupings are distinguished, namely managerial, professional, clerical, services, sales, and production. To distinguish these, we make use of occupation data

THE WORLD INPUT-OUTPUT DATABASE

To measure the value that is added by specific industries to global value chains, we have to trace production flows across countries and industries. The publicly available World Input-Output Database (WIOD) has been specifically designed for this purpose (Timmer et al., 2015, see www.wiod.org). This database provides annual tables of world input-output flows from 1995 onwards. The tables include information on 40 countries, including 27 EU countries (as of January 1, 2007) and 13 other major economies, including Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, Taiwan, Turkey, the United States, and South Korea. These 40 countries account for about 85% of world GDP. In addition, the rest of the world is modeled, which provides a full decomposition of the value added to final products. For each country in the database, 35 industries are distinguished, namely agriculture, mining, 14 manufacturing industries, construction, utilities, and 17 services sectors. The tables are constructed by combining national input-output tables with bilateral trade data, using conventions described in the system of national accounts. Also, information on capital use and different types of labor (low-, medium-, and high-skilled) is available.

For formulating policies, a strong statistical basis is needed to systematically use the method presented here. The WIOD is only a proof of concept, and it requires better institutional embedding. The "Made in the World" initiative at the OECD/ WTO and WTO (see the OECD/WTO Tiva database) is therefore very much welcomed, not only because it aims to update the type of data provided in the WIOD, but also as it aims to extend the country coverage and closely engages with statistical offices to reduce inconsistencies in the raw data. Another important initiative is the construction of the South American Input-Output Table by a team of researchers from ECLAC and IPEA (ECLAC 2016).

Much progress still needs to be made in relation to trade in services. Much of this trade takes place between subsidiaries and often involves special access to protected intellectual property. Recent surveys that measure the type of activities undertaken by firms will provide additional insights. In addition, the reward to intangible capital income (such as brand names and design) in value chains should be further examined.

from PNAD (for Brazil) and population censuses (for Mexico), while the data sources for the US are the same as in Autor (2015).

The rows in table 1 show the structure of labor income in Brazil, Mexico, and the US that derives from participating in the global value chains of final manufactured products. The summation of income from each activity in a particular year is equal to labor income.

The table also shows the change in labor income by activity between 1999 and 2007. As before, this is the value added for all manufacturing value chains in the world. In relative terms, the income of workers active during production declined from 49% to 38% in Brazil and from 50% to 47% in Mexico. Relative to the US, labor income from production activities is higher in Brazil and Mexico. This income is the product of the number of workers and their nominal wages. The change in the

TABLE 1
LABOR INCOME BY ACTIVITY IN GLOBAL VALUE CHAINS FOR MANUFACTURES

		MANAGERIAL	PROFESSIONAL	CLERICAL	SERVICES	SALES	PRODUCTION
BRAZIL	1999	7.5	16.3	10.7	6.9	10.2	48.6
	2007	15.7	22.5	8.9	9.1	6.1	37.7
	Change	8.2	6.2	-1.8	2.2	-4.1	-10.9
MEXICO	1999	12.9	14.1	6.6	4.6	12	49.8
	2007	9.9	20.3	5.6	4.4	12.9	46.9
	Change	-3	6.2	-1	-0.2	0.9	-2.9
US	1999	21.4	25.9	10.4	3.9	6.7	31.7
	2007	23.1	28.6	9,2	4.2	7.9	26.9
	Change	1.7	2.7	-1.2	0.3	1.2	-4.8

Source: Author's calculations using the World Input-Output Database and newly constructed occupations data.

income share is mainly due to a decline in the number of production jobs (not shown).

One potential explanation is modern technological change in the form of automation, which tends to replace workers performing routine tasks, which happen to be characteristic of many middle-wage occupations such as bookkeeping, administrative support, and production work (Autor, 2015). This compares to an increase in income by higher-skilled workers in pre- and postfabrication activities. For example, the income share by professionals increased from 16% to 23% in Brazil and from 14% to 20% in Mexico. Our findings suggest there are clear differences in job creation and remuneration depending upon the occupation considered.

These trends are clearly not only taking place in Latin America. The final rows in table 1 show the change in labor income shares by activity for the United States, where the share of production activities has also declined, whereas it has increased for professional and managerial activities.

A valid question is thus whether the specialization patterns in Brazil and Mexico are different from other countries. A well-known method to explore this is by means of revealed comparative advantage. Traditionally, this indicator is based on the use of world export shares. An alternative is to measure this indicator based on income shares in global value chains for final manufactured goods (see Timmer et al., 2013, for a comparison between the traditional measure and this new measure). In table 2, the revealed comparative advantage of Brazil and Mexico is measured relative to the other 40 countries distinguished in the World Input-Output Database (see box 1 for the list of 40 countries). For comparison, the results for the US are also shown in table 2.

The results suggest that Brazil and Mexico have a comparative advantage in production activities: the indicator is larger than 1 because the share of labor income from this activity is higher

AUTOMATION AND GLOBAL VALUE CHAINS

During recent decades, labor markets polarized as employment in low- and high-wage jobs increased relative to employment in jobs that used to be in the middle of the wage distribution (see Reijnders and de Vries, 2016, on evidence for Brazil and Mexico). These changes in job structure are different from earlier developments in the labor market. In the 1970s and 1980s, there was a clear demand shift in favor of more educated workers, which is often explained by the "skill-biased" nature of technological change. This type of technological change cannot rationalize the current bias against middle-skill workers relative to low- and high-skill occupations (Autor 2015). Instead, the "routinization hypothesis" has been developed, which states that modern technological change in the form of automation tends to replace workers performing routine tasks, which happen to be characteristic of many mid-wage occupations such as bookkeeping, administrative support and production work. This is often referred to as routine-biased technological change. In contrast to its demand-reducing effect on middling-wage occupations, this type of technological change complements analytical (high-wage professional and managerial) occupations and does not (yet) directly affect non-routine manual (low-wage sales and services) occupations and hence results in the polarization of the labor market.

Reijnders and de Vries (2016) find that automation drives down the demand for mid-wage occupations throughout the entire global value chain. For example, nowadays less production workers are needed to produce German cars relative to designers, engineers and sales workers as compared to a decade ago. Automation in the form of routine-biased technological change within global value chains affects the demand for production workers in each country involved in this global value chain.

compared to the other countries. Brazil and Mexico are also revealed to have a comparative advantage for several lower-wage activities in services and sales. The US is revealed to have a comparative advantage in low-wage services and sales activities, and higher-wage professional and managerial activities.

The example of iPhone assembly in Brazil that we started out with in the introduction is thus illustrative of the general findings presented in this article.

MULTILATERAL AGREEMENTS

Traditional measures of comparative advantage based on export statistics (see, for example, Bahar, Hausmann, and Hidalgo, 2014) are increasingly less adequate in formulating policy due to the international fragmentation of production. Brazil may export iPhones, but traditional export statistics do not show the value that is added. Intermediate inputs and the input from designers and engineers are performed elsewhere. The measure introduced in this article quantifies the value added by a country in a particular activity in global value chains. The increasing interconnectedness of activities also carries implications for the effects of trade agreements. Because products cross borders multiple times before they reach the final user, tariffs and other trade barriers

TABLE 2
COMPARATIVE ADVANTAGE IN ACTIVITIES

		MANAGERIAL	PROFESSIONAL	CLERICAL	SERVICES	SALES	PRODUCTION
BRAZIL	1999	0.45	0.69	0.97	1.90	1.65	1.25
	2007	0.87	0.82	0.94	2.33	1.06	1.07
MEXICO	1999	0.77	0.59	0.60	1.28	1.95	1.28
	2007	0.55	0.74	0.59	1.12	2.26	1.33
US	1999	1.28	1.09	0.94	1.07	1.09	0.82
	2007	1.28	1.04	0.97	1.08	1.39	0.76

Source: author's calculations using the World Input-Output Database and newly constructed occupations data.

may accumulate in production chains (Yi, 2003). In addition, the fact that value chains may involve multiple countries reduces the effectiveness of bilateral agreements. The fragmentation of production strengthens the need for low transaction, transport, and trade costs, and calls for multilateral trade agreements.

Finally, broader lessons can be derived for the education system. The fragmentation of value chains results in an international relocation of activities. Some activities will disappear and others (maybe entirely new activities to the country) will increase in importance. This calls for studies on appropriate policies for the labor market and the education system.

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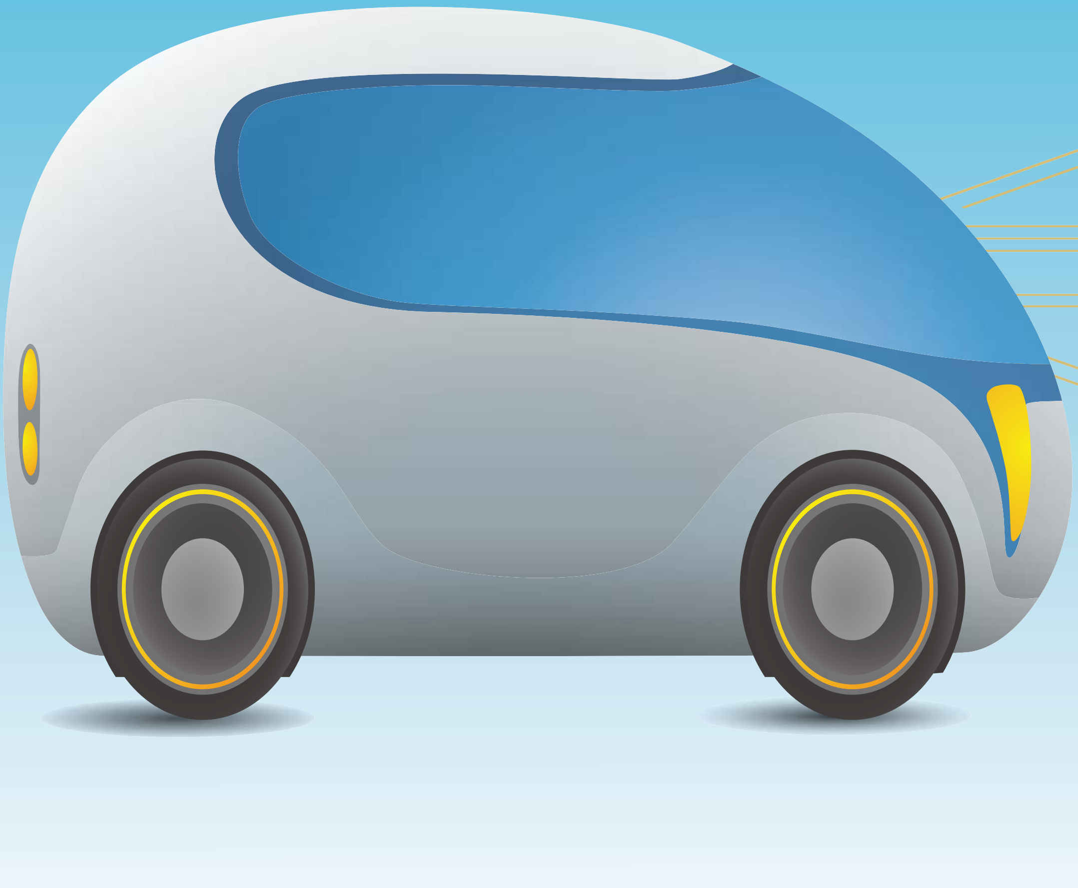
ANALYSIS

Offshoring



Bianca Pacini
University of San Andrés (UdeSA)
Luca Sartorio
University of Buenos Aires (UBA)

or reshoring?

The automotive industry

In the past, distances were greater,
because space is measured in time.

Jorge Luis Borges

DESPITE INITIAL IMPRESSIONS THAT MAY SUGGEST THE CONTRARY, USING ROBOTS IN PRODUCTIVE PROCESSES MAY FAVOR INTEGRATION THROUGH GLOBAL VALUE CHAINS BY INCREASING PRODUCTIVITY AND THE DEMAND FOR INTERMEDIATE GOODS. THIS ARTICLE ANALYZES THE RECENT DYNAMICS OF TRADE IN THE AUTOMOTIVE INDUSTRY.

Concern over the impact of automation on the labor market has recently been the subject of considerable debate in the world of economics. Indeed, research-based studies that have argued that technological progress threatens to replace a substantial number of jobs in developed economies have prompted the creation of specialist research teams in different countries and international organizations. Analyzing the impact of these disruptive changes has become an increasingly active field of study within labor economics. Much of this recent interest is due to its selection as the main focus of the 46th annual meeting of the Davos World Economic Forum in 2016.

The majority of this emerging literature has focused on just two fundamental objectives. First, it has sought to examine whether technological change has been the main driver for the polarization of labor market in developed countries in recent decades. Multiple studies have documented that, from the late 1970s onward, there has been a continuous drop in the share of medium-skill occupations over total employment in developed countries through a process of polarization that has increased the relative shares of both low- and high-skill jobs. The studies that have provided solid descriptions of the recent polarization of developed labor markets include Goos and Manning's (2007) analysis of the British economy between 1979 and 1999; Autor's (2014) study of the US economy between 1979 and 2012; and Goos, Manning, and Salomons's (2014) more extensive assessment of 16 European Union countries between 1993 and 2010.

As a consequence, different empirical studies have sought to establish causal links between biased technological change and these recent trends toward the polarization of occupational structures using diverse strategies for a large set of developed countries. Some of the more significant of these publications include Autor and Dorn (2013) for the US labor market between 1980 and 2005 and Michaels, Natraj, and Van Reenen (2014), who documented this causal relationship between 1980 and 2014 in the United States, Japan, and nine European countries.

Second, a set of alternative publications has tried to determine how these trends toward the technological substitution of employment will develop in the future by making ambitious estimates of the probabilities of all current jobs being automated. The most representative of these is Frey and Osborne's (2013) study of the US economy, which concluded that 47% of total employment was at high risk of being automated. This study has recently been called into question by Arntz, Gregory, and Zierahn (2016), who estimated analogous probabilities using an alternative methodology for a set of 21 OECD countries. They found that the percentage of jobs that were at risk of being replaced was no higher than 13% in any of the economies they analyzed (which included the United States). These findings are in line with another similar study carried out by the McKinsey Global Institute (2017), which concluded that only 5% of occupations are entirely made up of activities which it would be technically possible to automate.

Both types of publications have sought to shed light on phenomena with direct implications on income policies or social programs, labor market regulations, and changes to the design of educational programs. However, despite the considerable impact that disruptive changes and technical progress have on determining productive and trade strategies, the relationship between them and integration into global value chains (GVCs) has not received similar levels of attention in the literature, except for a few preliminary studies.

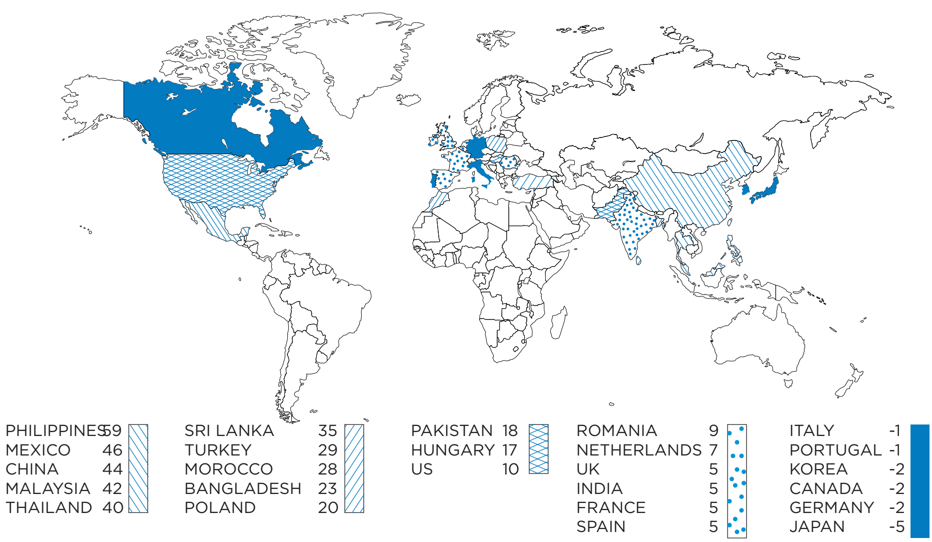
A report entitled *Technology at Work 2.0* (Citi, 2016), carried out by researchers at Citibank and Oxford University, and *Robots and Industrial-*

17%

THE ANNUAL GROWTH RATE FOR INDUSTRIAL ROBOTS SINCE 2010

FIGURE 1

CHANGE IN THE NATIONAL EXPORT MANUFACTURING SHARE PER COUNTRY, 1980-2007/2008 (PERCENTAGE POINTS)



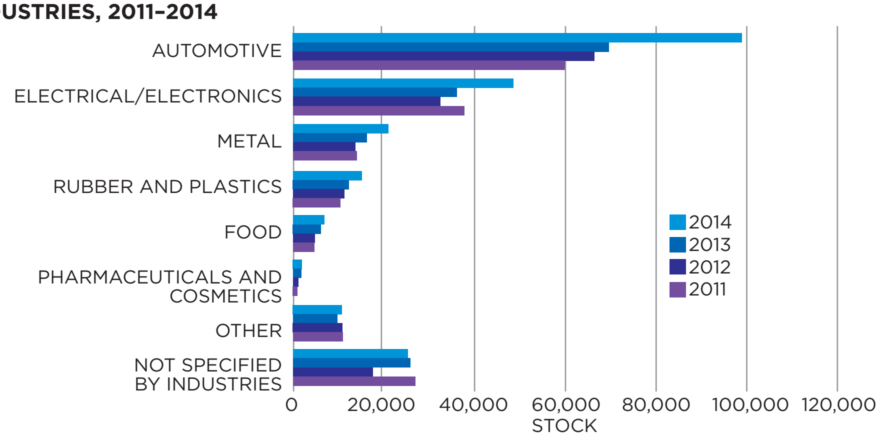
Note: Data for all nations with (1) population over 10 million, (2) manufacturing export share over 50% in 2007–2008, (3) at least 90% data coverage from 1985 to 2008.
Source: Baldwin (2013) based on data from the World Bank.

ization in Developing Countries, published by UNCTAD (2016), both put forward the hypothesis that the growing use of industrial robots in developed countries could replace jobs that were previously offshored to developing countries, which would erode the latter's traditional wage cost advantage. This process would give rise to a partial reversal of the trend toward offshoring manufacturing and assembly processes that have characterized emerging economies' role in GVCs in recent decades. This would give rise to a reshoring process in which countries with high endowments of robotic capital would start to rebuild multiple productive segments that they had previously offshored, which would increase their share in the generation of value in the GVCs in question.

Identifying GVCs in which there are trends toward a reversal of the offshoring process is potentially crucial to determining countries' strategies for integrating into the global production system. This study seeks to continue this line of research and put forward a new methodological tool that entails estimating gravity models for bilateral trade that allow us to recognize the partial effect of the growing stock of industrial robots on how far countries integrate into GVCs. This tool will allow us to identify the productive sectors in which there may indeed be a trend toward a reversal of the offshoring process. By comparing this partial effect among different productive sectors, this model may help determine how reasonable it would be, in terms of job creation, for each productive sector to pursue a medium-term productive integration strategy based on supplying low-skilled labor with a wage advantage.

We will illustrate this through the example of the automotive industry, which is the manufacturing sector that currently has the greatest endowment of robotic capital, according to data from the International Federation of Robotics (IFR). We will test whether the growth in the stock of industrial

FIGURE 2
ESTIMATED ANNUAL GLOBAL SUPPLY OF INDUSTRIAL ROBOTS BY MAIN INDUSTRIES, 2011–2014



Source: Citibank (2016) based on data from IFR.

robots in countries with high endowments of these was indeed a determining factor in the reversal of the trend toward offshoring through import substitution in recent years. If we find evidence to the contrary, technology's contribution to the growth in global automotive production may have stimulated demand for intermediate inputs. It thus may have further increased bilateral trade by further incubating GVCs through increased demand for intermediate inputs produced abroad.

In contrast to what has been suggested by the researchers at UNCTAD, Citibank, and Oxford University, we have found that there is a positive association between growth in industrial robotics in the automotive sector in countries with high endowments of robotic capital and trade in intermediate goods with these countries' main autopart suppliers. This effect is certainly explained by the increases in production generated by a greater endowment of robotic capital and the consequent increases in the need for intermediate goods imports.

This article is organized as follows. In section 2, we present the hypothesis of the reversal of industrial offshoring toward countries with low wage costs, as established in recent literature. Section 3 consists of a detailed explanation of the methodology we used to design our estimation tool. We then present the results of our impact evaluation of how the stock of industrial robots in the automotive sector in countries with high endowments of robotic capital impacts bilateral trade with these countries' respective suppliers of intermediate goods. Section 4 concludes the article with a brief summary and proposed future areas of research that arise from this study.

75%

OF INDUSTRIAL ROBOTS ARE CONCENTRATED IN JUST FIVE COUNTRIES

THE RESHORING HYPOTHESIS

In the mid-1980s, advances in telecommunications, computing power, and software development brought about the conditions for an ICT revolution that caused disruptive changes in the composition of international trade. As Baldwin (2013) has documented, the growing reach of these technologies and the rapid decrease in their cost made the geographical separation of manufacturing stages economically viable. Driven by economies of scale and comparative advantages, this fragmentation of the production process was enabled through improvements to the ability to coordinate and monitor production over long distances.

This is what Baldwin dubbed the "second unbundling,"[1] a process through which firms from high-income countries combined locally generated technology development, product design, and marketing strategies with the offshoring of manufacturing and assembly processes. This offshoring of the more labor-intensive segments to developing countries with abundant low-skilled labor led to gains in labor costs without major losses to the process of coordinating and monitoring production.

This proliferation of GVCs allowed developing countries to integrate into global production by exporting intermediate manufactured goods. Figure 1, taken from Baldwin (2013), indicates changes in the national export manufacturing share between 1980 and 2007–2008 for a broad set of countries. As can be seen in the figure, the major winners and losers in the share of industrial exports are highly concentrated around the US, Japan, and the European Union. Countries with increasingly industrialized exports are fundamentally those where wages are low, while the countries where industrial exports have become less significant are generally ones where wages are high.

However, some studies have begun to ask whether these trends will continue. This question is particularly relevant given the growing automation of employment through the use of industrial robotics, fundamentally in more repetitive and predictable segments such as manufacturing and assembly.

UNCTAD (2016) examined the possibility that the growing use of robots in high-income countries may threaten the wage cost advantage that characterizes developing countries with abundant supplies of low-skilled labor. According to estimates in a World Bank (2016) report, the share of occupations that may experience significant automation was actually higher in developing countries than in more advanced ones, where these jobs had already disappeared.

According to UNCTAD, this could lead to a reversal in the offshoring process in industrial segments, where different economic activities may be reshored back to economies that are incorporating industrial robotic capital, which would thus recover their international competitiveness in these segments. If this process were to intensify, it would make less sense in the medium and long term for low-income countries to pursue an integration strategy based on wage advantages as an alternative to industrialization.

The preliminary results of the Citibank (2016) report are along similar lines. First, this report stressed the importance of recent developments in global industrial robotics. Although industrial robots have been in use for at least four decades, the report noted that the process of robotization has accelerated sharply since the global financial crisis: average sales of industrial robots grew at a compound annual rate of 17% between 2010 and 2014, in comparison with a 3% rate between 2004 and 2008. The three drivers for this phenomenon were rapid increases in wage levels and population aging in large industrial countries, the falling prices of hardware and software technologies, and technical advances that have increased the scope and usability of industrial robotics.

Second, the report points out that not all industries and countries have benefited equally from this acceleration. Figure 2 shows global stocks of industrial robots by industry, according to IFR data. It shows that the use of industrial robots was highly concentrated in the automotive industry and the electrical and equipment sector. Figure 3 reveals how robotic installations in recent years have been concentrated in five countries: Germany, Korea, the United States, China, and Japan, which have accounted for nearly 75% of all recent installations. The graph shows China's strong growth throughout the period in question.

The Citibank (2016) report is an initial look at the issue and seeks to analyze whether the countries with the largest numbers of industrial robots have gained market share in global exports in the main two industries affected by growing robotization. If there really is a reshoring process underway, countries that have increased their robotic capital would be expected to have substituted imports from low-wage-cost countries and thus to have increased their share of total global exports in the sectors in question.

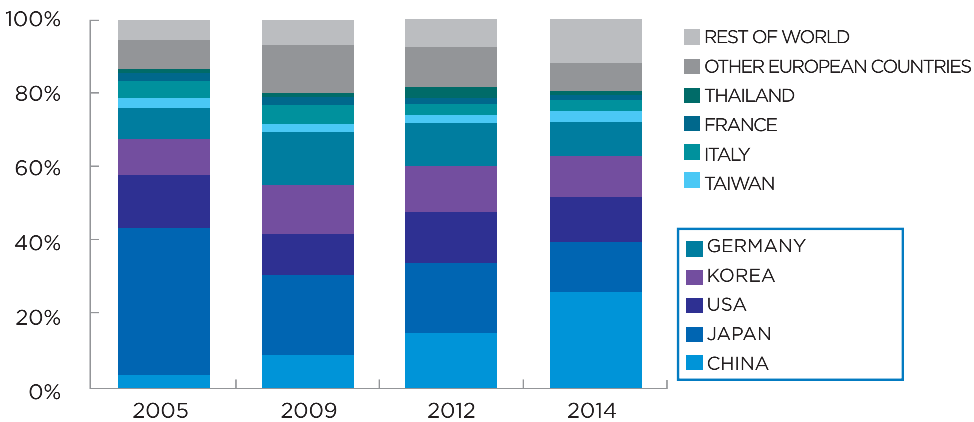
Figure 4 appears to confirm this trend, to a certain extent. Germany has maintained its share of the road vehicle market while that of other European countries has plummeted. The downward trend in both industries in the United States stopped during the period when growth in global robotics endowments began to accelerate. China's share in the vehicle and transportation equipment industry has grown strongly in line with its growing robotization. In contrast, there was a strong downturn in Japan's share in both industries, which is in keeping with the considerable drop (and loss of primacy) in its international market share in robotic installations. Korea's share in vehicles and transportation equipment grew but then slowed toward the end of the period, while the behavior of its electronics sector was more stable.

2%

THE INCREASE IN BILATERAL EXPORTS FOR EACH 10% INCREASE IN ROBOT NUMBERS

Although these trends would appear to provide evidence for a relationship between countries' export performance in the selected industries and their recent growth in industrial robotics, this analysis is only preliminary and does not consider several points of interest. The most important

FIGURE 3
COUNTRY SHARE IN GLOBAL ROBOTICS INSTALLATIONS



Source: Citibank (2016) based on data from IFR.

of these is undoubtedly the fact that a descriptive analysis of these characteristics does not provide sufficient evidence of the existence of a causal relationship between automation induced by the addition of industrial robotics and the partial reversal of trends toward offshoring.

Alternatively, the growth in industrial robotics may be associated with increases in the production of goods in the industries in question. These increases in production would generate a corresponding increase in demand for intermediate inputs. It would thus be plausible for there to be ensuing growth in the industrial imports from developing countries that are well-positioned in manufacturing and assembly sectors within the GVCs in question.

To analyze whether there is indeed a negative relationship between new installations of industrial robotics in the leading countries in the sector and exports of intermediate goods from their main trade partners, we would need to look more exhaustively at the determining factors for each bilateral trade relationship. To do so, in this article we propose to analyze this phenomenon by estimating a gravity model for bilateral trade in autoparts for three of the countries with the greatest endowments of industrial robots (Germany, China, and the United States) and their main trade partners.

THE IMPACT OF ROBOTICS ON TRADE

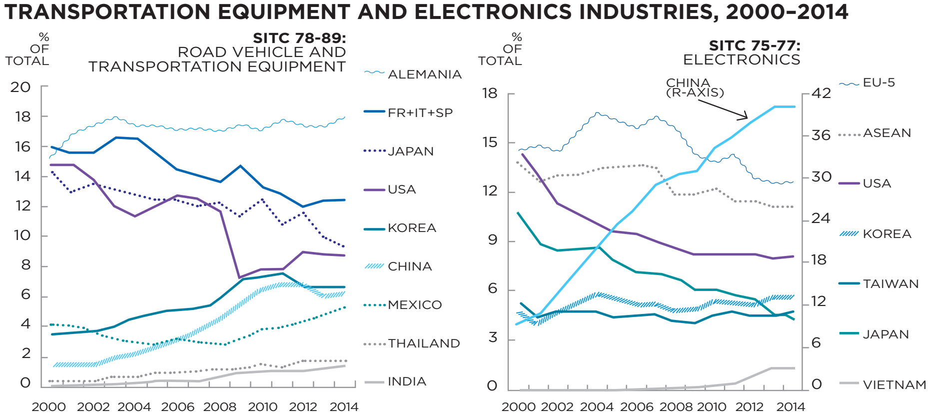
Methodology: The Gravity Approach

Our aim is to suggest an empirical estimation tool for analyzing the partial effect of the introduction of industrial robots on bilateral trade. To do so, we will analyze the multiple determining factors for bilateral trade by estimating a traditional gravity model and including the importer country's stock of industrial robots as the explanatory variable of interest.

Gravity models are a tool that is

FIGURE 4

SHARE IN EXPORT MARKET PER COUNTRY IN THE VEHICLE AND TRANSPORTATION EQUIPMENT AND ELECTRONICS INDUSTRIES, 2000–2014



Note: EU-5 refers to the five largest economies in the European Union.
Source: Citibank (2016) based on data from UN Comtrade.

widely used in the literature to describe the main determining factors for bilateral trade between countries. Initially conceived as a way of determining the effect of distance between two countries on the flow of trade in goods and services, they have since been used to estimate the effect of multiple determinants of trade such as trade agreements, tariff barriers, export subsidies, trade sanctions, currency unions, immigration, direct foreign investment, and cultural ties, among other factors.

In this study, we will estimate the following model under three specifications:[1]
ordinary least squares (OLS), with no fixed effects for each pair of countries:
(2)

$$
\begin{aligned}
&lnTradeValue_{eit}= \\
&= \alpha + \beta_1 \ln PBI_{it} + \beta_2 \ln PBI_{et} + \\
&+\beta_3 \ln RES_{it} + \beta_4 \ln RES_{et} + \beta_4 \ln DIST_{ei} + \\
&+ \beta_5\, CLNY_{ei} + \beta_6\, FRONT_{ei} + \beta_7\, LANG_{ei} + \\
&+ \beta_8\, RTA_{eit} + \beta_9 \ln Tariff f_{it} + \\
&+\beta_{10}\, ln\, Robots_{it} + \varepsilon_{eit}
\end{aligned}
$$

where $TradeValue_{eit}$ represents the value in current US dollars of the exports of country i (exporter) to country i (importer) for the period$t$; PBI_{it} and PBI_{et} represent the GDPs of the two countries, respectively; RES_{it} and RES_{et} are resistance indexes that function as approximations for the terms of multilateral resistance, the construction of which makes them unobservable[1] (Wei, 1996; Baier and Bergstrand, 2009).[2] Likewise,$DIST_{ei}$, $CLNY_{ei}$, $FRONT_{ei}$ and $LANG_{ei}$ are standard control variables used in gravity models: the first of these indicates the distance between countries measured in kilometers, while the other three are variables that take the value of 1 if the countries had colonial ties, have a common border, or share the same language, or the value of 0 if none of these factors apply. RTA_{eit} is a dummy variable that takes the value of 1 if countries had trade agreements during period t, and the value of 0 if they did not.$Tarif\ f_i$ indicates the average tariff set by country t for the autopart sector in period t. $Robots_{it}$ represents the stock of industrial robots in the automotive sector of country i during period t. Finally, $_{eit}$ represents the error term. The natural logarithm was applied to all continuous variables. For comparative purposes, we also included the same specification in the estimations in section 3.3 without controlling for resistance indexes [equation for model (1), see the "Results of the Estimation" section).

a) OLS, with fixed effects for each pair of countries:

One potential problem with the estimation of the suggested model is the possible endogeneity of the trade policy variables, RTA_{eit} and $Tarif\ f_{it}$ and time-invariant unobservable variables (Baier and Bergstrand, 2007). One solution to this obstacle is to include fixed effects for each pair of countries which control for all unobservable heterogeneity between countries which remains constant over time, regardless of the standard variables used in gravity models as described above, such as distance, shared borders, language, and colonial ties (Egger and Nigai, 2015; Agnosteva, Anderson, and Yotov, 2014).

In this case, we will apply OLS to the following linear regression model.
(3)

$$lnTradeValue_{eit} = \alpha +$$
$$+\beta_1 lnPBI_{it} + \beta_2 \ln PBI_{et} + \beta_3 lnRES_{it} +$$
$$+\beta_4 \, lnRES_{et} + \beta_8 \, RTA_{eit} + \beta_9 \, lnTariff_{it} +$$
$$+\beta_{10} \, lnRobots_{it} + \varphi_{ei} + \varepsilon_{eit}$$

where ϕ_{ei} captures all the fixed-time characteristics of the bilateral relationship between countries *i* and *e*. The disadvantage of including fixed effects for each pair of countries is that these absorb all time-invariant effects such as distance, shared borders, a common language, or colonial ties. However, this point is not relevant to the purposes of this article.

a) Poisson pseudo-maximum likelihood (PPML), with fixed effects for each pair of countries:

Santos Silva and Tenreyro (2006) showed that, in the presence of heteroscedasticity, the estimators for the log-linear regression under the OLS method may be biased and inconsistent. Given that heteroscedasticity is a common problem with trade data, we will apply the PPML method as an alternative to the models presented above, in keeping with the standards in the literature.

The model estimated under the PPML estimator takes the following form: (4)

$$TradeValue_{eit} = \exp[\,\beta_1 lnPBI_{it} +$$
$$+ \beta_2 \ln PBI_{et} + \beta_3 lnRES_{it} + \beta_4 \, lnRES_{et} +$$
$$+ \beta_8 \, RTA_{eit} + \beta_9 \, lnTariff_{it} +$$
$$+\beta_{10} \, lnRobots_{it} + \varphi_{ei}] \, \varepsilon_{eit}$$

If the relationship suggested by the publications mentioned in the previous section is verified, we would expect to find that the incorporation of industrial robotics (in the countries that top the global rankings of endowments in this area) to have a partial negative effect on exports of intermediate manufacturing goods from their main trade partners. If this relationship does not exist, we would expect to find that a greater stock of industrial robots does not substitute imports from countries that are suppliers of intermediate goods. Indeed, it may even increase demand for intermediate goods and intensify the bilateral trade relationship due to greater production of the final good in question.

To provide an example of an estimation using this tool, we will analyze the use of robotics in the automotive sector and the effect of this on bilateral trade in autoparts. This is not a random decision: the automotive industry has the greatest global endowment of industrial robots, as was shown in figure 2. We will analyze the model for bilateral trade in autoparts for three of the countries with the greatest stock of industrial robots according to figure 3 (Germany, China, and the United States) and their main trade partners in this area. We used a panel data structure for 2006–2015 for trade between the three countries in question and 49 trade partners that included their main autopart suppliers.

Data and Variables

The main sources of the data that we used to estimate the models in question were as follows:

- The values of the autopart exports included in our analysis were obtained from the UN Comtrade database, using Harmonized System (HS) heading 8708, which covers parts and accessories of motor vehicles.
- The GDPs of the countries included were taken from the World Bank database.
- The information on regional and bilateral trade agreements was taken from the detailed report available on the WTO Regional Trade Agreements Information System (RTA-IS).
- The average tariff structure of

importer countries for the products listed under heading 8708 was taken from the WTO Integrated Data Base (IDB).

· The stock of industrial robots in the automotive sector of the importer countries in question came from the database published by the IFR.

Results of the Estimation

In table 1 we present the results of the empirical estimations of the models described above. As can be seen, after controlling for the effect of multilateral resistances, the impact of increased stock of industrial robots in the automotive sector in Germany, China, and the United States on bilateral trade in autopart inputs is positive and significant under multiple specifications.

First, under OLS specification (1) without controlling for fixed effects or resistance indexes, the variable for the stock of industrial robots is not significant. After controlling for multilateral resistances (2), the effect of the variable on bilateral trade is positive and significant at 0.146: in other words, when the number of robots increases by 1%, there

TABLE 1
RESULTS OF THE ESTIMATION FOR THE SPECIFICATIONS FOR THE GRAVITY MODEL

VARIABLE	(1)	(2)	(3)	(4)
LN PBI_IT	0.413 (0.277)	-0.150 (0.217)	0.146 (0.248)	1.230*** (0.439)
LN PBI_ET	1.102*** (0.0984)	1.520*** (0.263)	0.939* (0.565)	-0.0650 (0.180)
LN DIST_EI	-0.824*** (0.255)	-1.061*** (0.231)	- -	- -
LN TARIFF_IT	-0.476*** (0.181)	-0.504*** (0.181)	1.558 (0.949)	1.421** (0.627)
FRONT_EI	0.239 (0.661)	0.0212 (0.616)	- -	- -
LANG_EI	-0.685 (0.437)	-0.577 (0.407)	- -	- -
CLNY_EI	1.192** (0.521)	1.039** (0.456)	- -	- -
RTA_EIT	1.231*** (0.423)	1.062*** (0.375)	0.375*** (0.0856)	0.307*** (0.0612)
LN RES_ET	- -	0.491 (0.302)	0.593 (0.462)	0.605 (0.427)
LN RES_IT	- -	0.912 (0.567)	-2.405* (1.238)	-1,607 (1.272)
LN ROBOTS_IT	**0.0262** (0.0759)	**0.146***** (0.0505)	**0.126**** (0.0484)	**0.207***** (0.0429)
RES INDEX	NO	YES	YES	YES
FIXED EFFECTS BY COUNTRY	NO	NO	YES	YES
OLS	YES	YES	YES	NO
PPML	NO	NO	NO	YES
OBSERVATIONS	1,190	1,190	1,190	1,190
R-SQUARED	0.591	0.606	0.606	0.972

Note: Standard errors grouped for each pair of countries and reported in parenthesis. *** p<0.01, ** p<0.05, and * p<0.1.
Source: Compiled by the authors.

is an average 0.146% increase in the value of input exports, all other things being equal. Robot stock also has a significant positive effect both when fixed effects are included under the OLS estimator (3) and the PPML estimator (4), which yield coefficients of 0.126 and 0.207, respectively.

We should stress that under specification (4), the partial effect of tariffs on exports from autopart supplier countries to Germany, China, and the United States is negative and significant. This result may be biased by the fact that we considered a simple average of the tariffs set by importer countries and not the specific tariff imposed on each particular country.[5]

RESHORING?

This article has sought to contribute to the study of how the increasing incorporation of technology may impact both the dynamics of bilateral trade and decision-making around strategies for integrating into GVCs. We believe that the gravity model we have suggested may prove useful in identifying the productive sectors in which the incorporation of robotics by countries spearheading the use of industrial technology has brought about the substitution of intermediate inputs imported from their main trade partners. In some cases, there may be evidence of a reshoring process, in which the countries with the greatest endowments of industrial robotics are increasingly reintegrating into productive segments of GVCs that they previously offshored, thus eroding the wage cost advantages of developing countries with abundant supplies of low-skilled labor.

However, in our specific evaluation of the automotive industry in 2006–2015, there did not seem to be evidence of this potential reshoring process. Instead, the stock of industrial robots makes a positive, significant contribution to bilateral trade under different econometric specifications. We can thus infer that countries' main aim when installing industrial robotics has not been to substitute intermediate inputs imported from abroad via automated local production. In contrast, these results suggest that this increase in robotic capital is associated with higher production volumes. Therefore, far from being a substitute for imported intermediate goods, increased use of robotics actually intensifies the complementary bilateral trade relationship between the countries included in the estimation.

However, we need to mention two final issues. First, the lack of reshoring processes in recent years does not mean that effects of this type might not occur in the future. Indeed, industrial robotics is expected to grow exponentially in the coming decades, which may alter the scale and characteristics of the phenomenon analyzed in this article. We may be at a very preliminary stage in the process we are analyzing and results such as those obtained here may not be good predictors of how these trends will evolve.

Second, this analysis is limited to the study of trade in autoparts in the automotive industry. We believe that the tool that we have put forward is especially useful for relative comparisons of different productive segments to determine which may involve substitution and reshoring processes and which may be characterized by complementarity and a subsequent intensification of offshoring processes. Future studies that apply the methodology we have suggested to a broader set of productive sectors may constitute an interesting contribution to this end.

METHODOLOGICAL NOTE

Anderson and Van Wincoop (2003) demonstrated that errors when considering the terms of multilateral resistance may lead to considerable biases in the estimation of variables for a gravity model. By introducing remoteness indexes, Yotov et al. (2016) suggest one way of contemplating multilateral resistance. In line with Head (2003), we constructed the indexes used in this article as follows:

$$lnRES_{et} = \ln\left(\sum Dist_{ei} \Big/ \frac{PBI_{et}}{PBI_t} \right)$$

$$lnRES_{it} = \ln\left(\sum Dist_{ei} \Big/ \frac{PBI_{it}}{PBI_t} \right)$$

NOTES

[1] As opposed to the first unbundling, which started with the steam revolution. This substantially brought down the cost of trade and transportation and made it viable for production and consumption centers to be geographically separate. This process was also stimulated by economies of scale and comparative advantages.

[2] In a study published by the World Trade Organization, Yotov et al. (2016) document a series of practical recommendations based on a synthesis of multiple empirical and theoretical developments from the literature, which we considered in this study.

[3] The importance of controlling for the terms of multilateral resistance is set out by Baldwin and Taglioni (2006). Olivero and Yotov (2012) propose controlling for multilateral resistance through fixed term exporter–time and importer–time effects. Even though this is highly efficient as a control mechanism, we did not pursue it as a strategy in this study given that the importer–time fixed effect would absorb the effect of our variable of interest.

[4] See methodological note.

[5] Our estimation of these specifications without including the tariff variable gave similar results with a positive, significant interest coefficient.

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CASE STUDY

PRECISION AGRICULTURE

DRONES AND SENSORS FOR MANUFACTURING FOOD

Robotics is opening up new ways of producing food. The cutting-edge technology used in precision agriculture allows producers to manage the agricultural, environmental, and economic aspects of their operations more efficiently. Some 34,600 robots are already in operation in this area.

The Institute of Automatics (INAUT) at the National University of San Juan (UNSJ) in Argentina is intensely engaged in training human resources, conducting research, and transferring knowledge in the field of robotics. It has developed applications for automating agriculture such as land-based and aerial robots that capture crop information. Through this work, it hopes to become part of an industry with an annual global turnover of US$1.5 trillion.

Carlos Soria, a member of the INAUT's board of directors, explains how robotization can improve agricultural productivity and how it can be complemented by the use of sensors, new developments in industrial electronics, and artificial intelligence–based systems.

What exactly is precision agriculture?

We are working on autonomous and remotely operated land-based robots and aerial vehicles that carry sensors and cameras to collect information on crops. The data they have collected is then processed and a downloadable, georeferenced map containing crop information is generated. There are several indexes that can be obtained using information from these cameras, but the commonest and the easiest for agronomists

20

MINUTES IS THE AVERAGE FLIGHT RANGE FOR DRONES CARRYING SENSORS

to interpret are the normalized difference vegetation index (NDVI) and the crop water stress index (CWSI). Agronomists can use the map to find out how each crop is growing, where more water is needed, if there are soil problems, what the soil type is, and if agrochemicals should be applied. This ensures optimal use of agrochemicals and water, as the information that the robot provides reveals precisely where they are lacking. The main sensors we use for these developments are visual. To reconstruct crop structure, we use a stereo setup of two normal cameras or laser sensors, although these are more expensive. We use multispectral cameras for the NDVI and thermal imaging cameras for the temperature variables. These sensors provide information on the growth and state of the crop.

What specific applications have you developed for Latin America and the Caribbean?

We have developed two main applications. One of these is a robotized ATV that either moves independently using GPS or is remotely operated. It roams up and down rows of olive or fruit trees and has a battery life of up to 4 hours. Other applications include four-, six-, and eight-rotor drones that have a flight range of between 15 and 20 minutes and a sensor-carrying capacity of about 500 grams. These capture data on the crop from a height of more than 10 meters, which is then processed and may be complemented by data from the ground-based robot. We have tested both applications in San Juan province, where vineyards and olive groves are the main crop environments. During the trial phase, we worked at the San Juan Experimental Station, which is run by the National Institute of Agricultural Technology (INTA), where we tested the navigation control algorithms for the robots and their visual sensors. The drones were tested on large-scale private soy, maize, and wheat farms in Córdoba and Buenos Aires provinces.

34,600

NEW ROBOTS WILL BE USED IN GLOBAL AGRICULTURE BETWEEN NOW AND 2019

US$ 1.5 trillion

THE ANNUAL TURNOVER THE GLOBAL ROBOTICS INDUSTRY IS ANTICIPATING FOR AGRICULTURAL APPLICATIONS

How can agriculture benefit from robotics?

There are four areas in which agriculture can be automated: at the measuring stage, to collect data and generate maps; during planting; while the crop is growing; and at harvest time. At INAUT we are working on the second and third phases. Maps allow agronomists to predict how the productivity of the land will evolve: we can use these images to know what the harvest will be like in advance. Agronomists can also use this information to make decisions on what inputs to apply to support and increase production. We have started work on an intelligent crop input application system that will be ready in two years. For example, if a crop-monitoring robot detects that a given agrochemical is needed, a valve will open automatically to apply this. The same thing will happen if a certain part of a plantation needs to be watered. We are developing image- and data-processing algorithms so that the robots can learn to use their visual sensors to detect weeds or a need for water.

How will robotics impact rural employment?

I think that robotics will benefit the health and safety of those who work in agriculture and society as a whole, because it will improve harvests and optimize land use, agricultural resources, and inputs. If robots are used to apply agrochemicals, for example, there will be no need for a human operator to be exposed to these substances. Robots can also be used at harvest time to prevent workers from having to carry heavy loads. In my view, the benefits outweigh the disadvantages. In this part of the country, the main two crops, olives and grapes, are mostly harvested by machine. Farmworkers who are responsible for monitoring and caring for crops need to know how to use these new technologies: how to use a tablet or a laptop, or how to read a digital map of the sown area. These processes imply a qualitative leap in the use of technology and user skill. As these technologies are introduced in the field, the idea is that workers will adopt them. They are simply tools and workers need to be trained to use them.

What challenges arise when people interact with robots in their work environment?

The idea is that robots will become increasingly safe and intelligent to ensure that they cause people no harm. At the same time, people will need to accept them and allow them to become just another tool that helps them do their job. Many academic research projects are currently examining the interactions between humans and robots with a view to improving these. One project is currently looking at how robots approach people, to find a way that isn't alarming.

MILLENNIAL

Results from the INTAL-VOICES survey of young Argentinians.

64% BELIEVE THAT THE GOVERNMENT SHOULD PROMOTE INTEGRATION WITH OTHER COUNTRIES IN LATIN AMERICA, WHICH IS THE REGION THEY LOOK MOST FAVORABLY ON.

41% THINK THAT LIMITS SHOULD BE PLACED ON IMPORTS OF GOODS TO PROTECT JOBS.

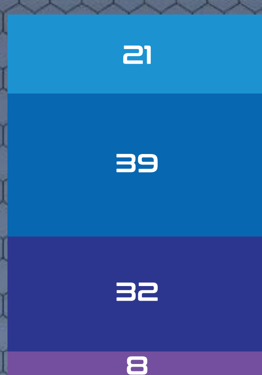
39% ARE OF THE OPINION THAT IT IS ACCEPTABLE TO LET FOREIGNERS COME TO LIVE IN ARGENTINA AS LONG AS THERE ARE JOBS AVAILABLE.

25% HAD USED AN ONLINE PLATFORM TO BUY OR SELL PRODUCTS OR SERVICES IN THE LAST MONTH BUT ONLY 11% DO SO REGULARLY.

SOLIDARITY WITH IMMIGRANTS

Which of the following measures do you think the government should adopt toward people from other countries who come to work in Argentina?

- Allow anyone who wants to come to come
- Allow people to come as long as there are jobs available
- Put strict limits on how many foreigners can come to work in Argentina
- Forbid people from other countries from coming here
- Don't know/no response



SOURCE: COMPILED IN-HOUSE BASED ON THE INTAL-VOICES SURVEY. 2017.

ANALYSIS

Anti-innovation bias?

The technological impact of trade agreements

Experience is not what happens to a man; it is what a man does with what happens to him.

Aldous Huxley

Santiago Chelala
INTAL/IDB

Inmaculada Martínez-Zarzoso
University of Göttingen and Universitat Jaume I

IN RECENT YEARS, A GROWING NUMBER OF COUNTRIES HAVE SIGNED TRADE AGREEMENTS THAT INCLUDE SPECIFIC CLAUSES ON TECHNOLOGY TRANSFER. IN THIS STUDY, WE EXAMINE THE ACTUAL EFFECTS OF THESE AGREEMENTS ON HIGH-TECHNOLOGY EXPORTS AND INDICATORS RELATED TO INNOVATION AND NEW TECHNOLOGY IN SIGNATORY COUNTRIES. WE DO SO BY ESTIMATING A GRAVITY EQUATION FOR BILATERAL TRADE FLOWS BETWEEN COUNTRIES IN THE AMERICAS AND THEIR MAIN TRADE PARTNERS.

Just as overprotection of a domestic market can give rise to an anti-export bias, can greater openness give rise to an anti-innovation bias, in certain circumstances? Or, in contrast, do the mechanisms set out in these trade agreements function in such a way as to allow signatory countries to close the technology gap between them? In this text, we attempt to measure the impact of trade agreements on countries' innovation performances.

Trade agreements increasingly address more than just tariffs. Chapters on technology transfer, investments, migration, and social and environmental standards have been added to the classic negotiations around eliminating barriers to trade (Baumann, 2016). In this way, they complement the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which entered into force in 1995. The main objectives of this agreement are, among others, "to promote the protection of intellectual property rights and contribute to the promotion of technological innovation and the transfer and dissemination of technology" (preamble, articles 7–8).

At the same time, there are growing expectations that trade agreements will bring benefits for signatory countries in the many areas where it is hoped some sort of trade will take place. One of the aspects of trade that has been studied most is the impact of foreign investment agreements, which has been examined by Egger and Pfaffermayr (2004), Jang (2011) and Bae and Jang (2013), among others.

The literature on technology and trade is also vast. Keller (2004) studies the international spread of technology and different propagation mechanisms, with a particular focus on the role of multinational companies. Hoppe (2005) examines the role of trade in economic development through its impact on technology transfer, measured through total factor productivity. The factors the author considers to be essential to this process include market openness, learning by doing, and the wide range of available technologies that increase trade. Maskus and Saggi (2013) analyze the role of innovation networks at the global scale and the effects they have on the multilateral trading system. Maskus (2016), meanwhile, stresses that regional trade agreements (RTAs) may play a major role in the dissemination of technology and the exchange of technological knowledge flows and in generating new trade-based public goods.

This study continues with this line of research and the approach taken by Baghdadi, Martínez-Zarzoso, and

Zitouna (2013) and Martínez-Zarzoso (2016) in examining environmental provisions in trade agreements. We use a gravity model that explains the determinants of bilateral trade flows, including the entry into force of trade agreements that include technology transfer clauses. The model was estimated using panel data techniques and by applying the Poisson pseudo-maximum likelihood method, in keeping with the most recent developments in the literature on international trade.

3
COUNTRIES IN THE REGION HAVE SIGNED TECHNOLOGY EXCHANGE AGREEMENTS WITH CHINA

EXCHANGES OF TECHNOLOGY: STYLIZED FACTS

The different articles that make up the texts of a trade agreement may or may not contain explicit decisions on trade in technology. In this study, we have differentiated between four areas where such exchanges typically tend to take place within free trade agreements (FTAs) and economic integration agreements (EIAs). These areas are as follows.

1) Technical cooperation.
2) Technology transfer.
3) Research, development, and innovation.
4) Patents and intellectual property.

Table 1 was compiled based on the texts of 12 agreements signed by Latin American countries and summarizes the contents of these in relation to intention to engage in exchanges of technology. The first row, China–Chile, thus considers article 68 of the treaty between these two countries, which establishes mechanisms for technical cooperation and technology transfer in specific industrial sectors and mining. It also looks at article 106, which establishes an exchange mechanism for research and development (R&D), and article 111, which establishes the rules on intellectual property. The second row of table 1 examines the content of the agreement signed between China and Peru, which establishes technical cooperation in different areas and mentions "the parties' recognition of the importance of intellectual property rights in the promotion of social and economic development, particularly in the globalization of trade and technological innovation as well as the transfer and spread of technology" (article 144). Article 148 addresses matters of cooperation and capacity building and article 155 looks at specific issues of technology transfer for the development of small and medium-sized enterprises. Table 1 summarizes the contents of 12 agreements and was compiled by following the approach described above for the remaining countries.

The three agreements with China explicitly include the four technology factors considered here. So do the USA's agreements with Peru and Costa Rica, although the former does not include any of these clauses in its agreement with Colombia and only three of them appear in its agreement with Chile. Canada includes just one aspect, technical cooperation, and leaves out the other three (except in its agreement with Peru, where it also includes R&D).

One legitimate question in this regard is whether these "parallel exchanges," which do not form part of the hard core of trade negotiations but are nonetheless present in most modern agreements, have had any type of concrete impact in signatory countries, particularly on factors related to innovation and new technologies.

To this end, we have compared trade agreements that include provisions on technology with those that do not to find out whether these clauses had the desired effect. However, this entails an additional difficulty: objectively measuring a country's technological evolution or its innovation performance is no easy task.

The literature on innovation processes and technology transfer uses indicators which range from the number of patents filed to the number of international publications by the country's researchers, or even the percentage of firms that have their own website. In this initial approximation, we have used two traditional indicators: the level of R&D expenditure in relation to GDP and the evolution of high-technology exports, and the relative number of patents, researchers, and technicians in relation to the total population.

We wondered specifically if the increase in the number of agreements that contain technology transfer clauses has functioned as an incentive for a country to invest in innovation. We also considered whether these agreements have increased each country's capacity for exporting high-technology products.[1]

A sample of countries and the gravity model used by Baghdadi et al. (2013) revealed relationships between these variables. The following section presents the methodology used to analyze the impact of the trade agreements that Latin American countries have signed in recent decades so as to

TABLE 1

CONTENT RELATING TO TRADE IN TECHNOLOGY IN SELECTED TRADE AGREEMENTS SIGNED BETWEEN LATIN AMERICAN COUNTRIES AND CHINA, THE US, AND CANADA

ENTRY INTO FORCE	COUNTRIES	TECHNICAL COOPERATION	TECHNOLOGY TRANSFER	R&D AND INNOVATION	PATENTS AND INTELLECTUAL PROPERTY
10/01/2006	CHILE-CHINA	YES	YES	YES	YES
01/03/2010	PERU-CHINA	YES	YES	YES	YES
01/08/2011	COSTA RICA-CHINA	YES	YES	YES	YES
01/01/2004	CHILE-USA	YES	No	YES	YES
01/02/2009	PERU-USA	YES	YES	YES	YES
15/05/2012	COLOMBIA-USA	No	No	No	No
31/10/2012	PANAMA-USA	YES	YES	YES	YES
15/08/2011	COLOMBIA-CANADA	No	No	No	No
05/07/1997	CHILE-CANADA	YES	No	No	No
01/11/2002	COSTA RICA-CANADA	YES	No	No	No
01/04/2013	PANAMA-CANADA	YES	No	No	No
01/08/2009	PERU-CANADA	YES	No	YES	No

Source: Compiled by authors based on the legal texts of the agreements, WTO, and OAS.

arrive at an overview of the effect that trade agreements may have on countries' technological development.

IMPACT ON INNOVATION

Hypothesis and Empirical Strategy

Generally speaking, the literature on the issue shows that international trade increases the competition and thus the incentive to create new products. Likewise, it accelerates technology transfer by introducing new products to foreign markets and encouraging the development of new ideas. Trade generally brings down the prices of products and thus encourages the use of new technologies by bringing down the cost of these. The increase in market size that comes with the elimination of barriers to trade generates scale economies that allow firms to recoup their investments in R&D more easily.

When liberalization and the consequent increase in trade are due to the signing of FTAs, there are two potential effects on technology transfer and innovation. First, the pure effect of the increase in trade due to the reduction of tariffs and nontariff measures, which will indirectly give rise to the effects described in the previous paragraph. Second, if the trade agreements in question are next-generation and include the explicit measures on trade and technology mentioned in the introduction to this article, it is reasonable to expect these to cause a direct effect, which may vary depending on the type of clause used to promote technology transfer and innovation (TTI).

In contrast, in the specific case of Latin America, as in other developing regions, trade openness may lead to a "primarization" of the economy, if there are additional incentives to increase sales of commodities with limited incorporation of technology.[2]

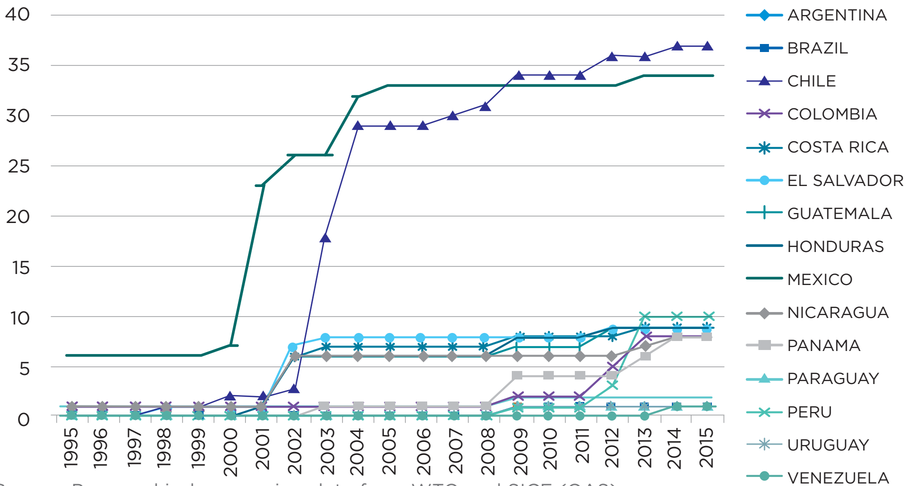
Isolating the pure effect of the increase in trade from the effect that comes from the inclusion of these clauses is no easy task.[3] The first part of the method used here consisted of estimating a gravity model to identify the determinants of bilateral trade flows. The model considers trade agreements and distinguishes between those that include innovation clauses and those that do not. This estimation will allow us to test whether agreements that do contain innovation clauses have an effect on exports, particularly whether they have a greater effect on exports of high-technology products. The first hypothesis is thus that agreements containing TTI clauses encourage an increase in exports of technology-intensive goods.

In the second part, we seek to determine whether the technology transfer that is generated through international trade (in relation to both ideas and products) significantly reduces the technology gap between countries. We also ask whether a certain number of agreements is needed for a significant impact to be generated.

Using the prediction obtained in the gravity equation, we estimate a model for the factors that determine technology or innovation gaps between countries. Given that innovation and technology are largely public goods, they lend themselves to cross-border dissemination (Grossman and Helpman, 1990; Coe and Helpman, 1995). New products can be copied without incurring high costs, and the capacity to adopt new technologies

FIGURE 1

NUMBER OF TRADE PARTNERS WITH AGREEMENTS IN FORCE CONTAINING TTI CLAUSES



Source: Prepared in-house using data from WTO and SICE (OAS).

and develop new products depends partly on the levels of human and physical capital in countries that could potentially adapt them. Consequently, human capital also has an influence on the speed at which new technologies are transmitted (Coe, Helpman, and Hoffmaister, 1997).

Specification of the Model

The gravity model has been widely used to predict bilateral trade flows between countries in recent decades and is considered a "warhorse" for the analysis of international trade (Feenstra, 2004), given that it is a structural model with solid theoretical underpinnings (Eaton and Kortum, 2002; Anderson and Van Wincoop, 2003; Allen, Arkolakis, and Takahashi, 2014). It is particularly appropriate for estimating the effects of trade policy and the importance of the costs of trade that are associated with distance and trade facilitation. Two of the model's most widely appreciated properties are its structure, which can flexibly accommodate the factors that affect trade, and its predictive power for aggregate trade flows.

In its simplest form, the gravity model as applied to trade predicts that the bilateral exports between two countries are directly proportionate to the product of their economic "mass" and inversely proportionate to the costs of trade (distance) between them. New techniques for estimating the model emerge continually, based on theoretical developments, which has given rise to a series of "practical" recommendations that were well documented in Head and Mayer (2014) and more recently in Larch and Yotov (2016) and Piermartini and Yotov (2016). Following these developments, the classic specification of the gravity model is:

(1)

$$X_{ijt} = Exp\begin{bmatrix}\delta_{ij} + \tau_{ip} + \varphi_{jp} + \alpha_1 \ln Y_{it} + \\ +\alpha_2 \ln Y_{jt} + \alpha_3 \ln Pop_{it} + \\ +\alpha_4 \ln Pop_{jt} + \\ +TP_{ijt} + \sum_k \beta_k RTA_{k\_ijt}\end{bmatrix} \varepsilon_{ijt}$$

where t represents the year and p periods of several years. X_{ijt} are the exports from country i to country j in period t in curent dollars.

The fixed effects associated with (bilateral) trade, δ_{ij}, represent the time-invariant characteristics of the trade relationship between i and j, y and are included to prevent biases due to unobservable factors that affect trade. Given that fixed bilateral effects absorb the influence of variables that are bilateral and time-invariant—such as geographical distance, a shared language, or a shared border—it is impossible to estimate coefficients for these factors directly.

Exporter-time (τ_{ip}) and importer-time (ϕ_{jp}) fixed effects represent all manner of trade barriers that are country-specific and vary slowly over time. The assumption is that they should control for both external and domestic multilateral resistance, that is, third-party countries' barriers to trade that affect the costs of trade. We used 4- to 10-year windows (p) to construct the exporter-time and importer-time fixed effects, mainly to account for factors such as institutions, infrastructure, or cultural factors that vary slowly. Y_{it} (Y_{jt}) indicates the exporter's (importer's) GDP, and Pop_{it} (Pop_{jt}) are the popula-

TABLE 2
RESULTS OF THE GRAVITY MODEL FOR TOTAL EXPORTS AND EXPORTS BY TECHNOLOGY LEVEL

Method: ppml_BTFE **VARIABLES**	**(1) Xt**	**(2) Xht**	**(3) Xmt**	**(4) Xlt**
IN Y_EXP	0.592*** (0.060)	0.714*** (0.076)	0.649*** (0.078)	0.757*** (0.078)
LN Y_IMP	0.777*** (0.098)	1.290*** (0.094)	0.723*** (0.102)	0.866*** (0.099)
LN POP_IMP	-1.626*** (0.516)	-4.466*** (1,019)	-1.247** (0.595)	-2.603*** (0.698)
LN POP_EXP	0.968** (0.438)	0.953 (1,003)	0.120 (0.609)	0.116 (0.653)
RTA_TECH	0.221*** (0.051)	0.252** (0.137)	0.143* (0.075)	0.196* (0.114)
RTA_NOTECH	0.039 (0.037)	0.125 (0.098)	-0.084 (0.054)	-0.148 (0.100)
OBSERVATIONS	23,202	23,013	23,139	23,097
R^2				
NUMBER OF ID	1,112	1,103	1,109	1,107

Note: Heteroskedasticity-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Xt indicates total exports; Xht, Xmt, and Xlt indicate high-, medium-, and low-technology exports, respectively. All estimations contain bilateral fixed effects (PTFE) and multilateral resistance factors (MRT). Ppml indicates Poisson pseudo-maximum likelihood.
Source: Compiled by the authors.

tions of the exporter (importer).

The variable RTA denotes that both countries (country pair *ij*) are members of trade agreements in period *t*, where *k* indicates whether the agreement contains TTI clauses (k=1) or does not (k=0). TP_{ijt} represents time-variable bilateral factors, such as being a member of a currency union or the WTO.[4] Finally, ε_{ijt} is the error term, which is assumed to be identically or independently distributed.

Estimating the coefficient for the *RTA* variable allowed us to evaluate the change in bilateral exports using information from before and after the signing of each agreement, indicating whether or not exports between each pair of RTA member countries have increased significantly as a consequence of access to the integration area.

To determine if trade and technology-related clauses in trade agreements give rise to technology diffusion on the basis of the theoretical considerations that we have set out thus far, we are proposing a variation on the model to identify the determinants for the innovation gap, which is given by the following equation:

(2)

$$\left|\ln\left(\frac{RD_{it}}{RD_{jt}}\right)\right| = \gamma_{ij} + \delta_t + \gamma_1 \left|\ln\left(\frac{RRD_{it}}{RRD_{jt}}\right)\right| + \gamma_2 \left|\ln\left(\frac{TRD_{it}}{TRD_{jt}}\right)\right| + \gamma_3 \left|\ln\left(\frac{\widehat{Open}_{it}}{\widehat{Open}_{jt}}\right)\right| + \gamma_4 \left|\ln\left(\frac{IPR_{it}}{IPR_{jt}}\right)\right| + \gamma_5 \ln \widehat{Biltrade}_{ijt} + \gamma_6\, RTA_{k\_ijt} + \varepsilon_{ijt}$$

where RD_{it} (RD_{jt}) is R&D expenditure as a percentage of GDP in country *i* (*j*) over period *t.* The number of patents per inhabitant (Pat_{it}/Pat_{jt}) and the number of articles in technical and scientific journals (STJ_{it}/STJ_{jt}). will also be used as alternative dependent variables. RRD_{it} (RRD_{jt}) is the number or researchers per million inhabitants in *i*(*j*), respectively, over period *t*, TRD_{it} (TRD_{jt}) is the number of technicians per million inhabitants in *i*(*j*), respectively, over period *t*, $\widehat{Open}_{it}$ ($\widehat{Open}_{jt}$) is the coefficient of openness to trade and was obtained by aggregating export predictions by country of origin (destination) *i* (*j*).[5] IPR_{it} (IPR_{jt}) is intellectual property in *i* (*j*) for period *t*. $\widehat{Biltrade}_{ijt}$ is the prediction of trade between countries *i* and *j* over period *t* and RTA_{k_ijt} are dummy variables that take the value 1 when *i* and *j* have a trade agreement in force in period *t* with the country (k=1) that includes TTI clauses, and 0 when this is not the case. γ_{ij} represents the inclusion of bilateral fixed effects in the estimation to mitigate endogeneity; and δ_t indicates the inclusion of time fixed effects to control for time-variable factors that affect all country pairs in a similar fashion, such as the technological frontier within the global market.

Finally, to evaluate whether there needs to be a critical mass of agreements for there to be an effect on the innovative capacity of countries in Latin America, we estimated a third model. This uses variables that measure innovation as the dependent variable, while the main explanatory variable is the cumulative number of agreements containing TTI clauses. We were thus able to build a panel that included 14 countries and their respective trade agreements, following the example given in table 1.

Data and Variables

The data on trade was extracted from UNCTAD's trade series while that on innovation came from the World Bank's development indicators. The texts of the trade agreements were taken from the WTO and the Organization of American States (OAS) Foreign Trade Information System (SICE), which gathers information on trade agreements in Latin America and the Caribbean.[6]

Figure 1 shows the disparities in the numbers of trade agreements signed by Latin American countries that contain TTI clauses. As can be seen, Chile and Mexico are the most active countries in this area, with more than 30 agreements in force.

Main results

The estimations of the gravity model are presented in table 2. The first column presents the results for total exports, while columns 2 to 4 show the results for high-, medium-, and low-technology exports. The coefficient of the trade agreement variable with TTI clauses (RTA_tech) is positive and significant for total exports (column 1), and for technology-intensive exports (column 2), but is not significant for agreements that do not contain TTI clauses (RTA_notech).[7]

The effect is greater for high-technology exports (column 2) and for the rest. For low- and medium-technology exports (columns 3 and 4), the coefficient is significant at 10% (*), which indicates that it was estimated with less precision than column 2.

Countries that are members of agreements containing TTI clauses traded 25% more following the entry into force of these agreements than countries that are not party to these. The effect increases by up to 29% if

TABLE 3
ESTIMATIONS OF THE MODEL FOR THE INNOVATION VARIABLES

DEP. VARIABLES GAP IN:	(1) RD gap	(2) Pat	(3) STJ	(4) RD	(5) Pat	(6) STJ
EXPL. VARIABLES LN RRD	0.258*** (0.032)	0.102 (0.120)	0.333*** (0.059)	0.268*** (0.031)	0.127 (0.120)	0.355*** (0.060)
LN TRD	0.064*** (0.008)	0.101** (0.051)	0.020 (0.014)	0.064*** (0.009)	0.103** (0.052)	0.023 (0.015)
LN IPR	0.015 (0.020)	0.002 (0.046)	0.069* (0.038)	0.015 (0.019)	0.010 (0.046)	0.068* (0.037)
LN BILTRADE	0.035** (0.017)	-0.089 (0.087)	-0.124*** (0.027)	0.036** (0.017)	-0.106 (0.089)	-0.136*** (0.028)
LN OPEN	0.032*** (0.011)	0.098** (0.042)	0.116*** (0.025)	-0.736*** (0.241)	0.756 (0.646)	0.330 (0.514)
RTA_TECH	-0.131*** (0.048)	-0.313*** (0.102)	-0.109 (0.068)	-0.138*** (0.047)	-0.247** (0.103)	-0.055 (0.074)
RTA_NOTECH	0.002 (0.011)	1.159*** (0.061)	0.087*** (0.026)	0.012 (0.011)	1,141*** (0.062)	0.074*** (0.026)
OBSERVATIONS	2,893	2,607	2,847	2,970	2,678	2,925
NUMERO OF ID	420	372	420	423	374	423
ADJUSTED R-SQUARED	0..344	0.099	0.295	0.340	0.091	0.251

Note: Heteroskedasticity-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. RD, Pat, and STJ indicate the R&D gap between countries as a percentage of GDP, the patent numbers per inhabitant, and the number of articles in technical and scientific journals.
Source: Compiled by the authors.

high-technology exports are included.

Table 3 presents the estimations of equation (2) for three dependent variables: the gap in R&D, the gap in patent numbers, and the gap in numbers of scientific and technical articles. The first part of the table estimates equation (2) with bilateral and time fixed effects, while the second part includes lags for the key variables (the first five lags)[8] to better control for the possible endogeneity of trade variables (open, Biltrade, RTA) in the model. The second part of the table shows that the agreements containing TTI clauses reduce the gap in R&D expenditure as a percentage of the GDP of countries that are party to the agreement (column 4, RTA_tech coefficient = -0.138) and reduces the gap in the number of patent applications per inhabitant (column 5, RTA_tech coefficient = -0.247). In the first case, the reduction is 15%, and in the second, a cumulative 28% comparing the situation before and after the agreements were signed. There is no significant effect on the gap in numbers of publications (columns [3] and [6]).

Finally, in table 4, we have aggregated the different components of the estimation to calculate the pure effect on levels of R&D expenditure and

THE TECHNOLOGY GAP AND EMPLOYMENT

This study analyzes the effect of trade agreements on technology exports and on the technology gap in general.

It is thus related to a vast literature that links the level of innovation in an economy with its labor markets. This literature dates back to Galí's (1996) pioneering study that showed the positive effect of technology shocks on factor productivity.

With regard to international integration, certain technologies have a multiplier effect. According to Baldwin (2006), advances in information and communication technologies (ICTs) function by bringing down costs and facilitating the inclusion of a given country into global productive chains by acquiring greater skill in the remote coordination and monitoring of production, which then impacts employment. This is just one example of how narrowing the technology gap can create new employment and integration opportunities.

At the same time, innovation can affect the labor market by altering both the wage gap and net job numbers. By way of example, Bloom, Draca, and Van Reenen (2011) define "task-biased technical change" as a phenomenon in which technical change affects jobs by replacing routine tasks.

Other nuances of the relationship between technology and employment are examined throughout this issue of *Integration & Trade Magazine.*

TABLE 4
ESTIMATIONS OF THE MODEL FOR THE INNOVATION VARIABLES: AGGREGATE COMPONENTS

VARIABLES	(1) Ln RD	(2) InPat-residents	(3) Ln Pat nonresidents
LN BILTRADE	0.112** (0.035)	0.253** (0.059)	0.076** (0.028)
RTA_TEC1	0.242* (0.132)	0.663*** (0.175)	-0.175 (0.204)
TIME FIXED EFFECTS	YES	YES	YES
COUNTRY FIXED EFFECTS	YES	YES	YES
OBSERVATIONS	185	218	231
NUMBER OF ID	16	18	19
ADJUSTED R-SQUARED	0.025	0.154	0.451

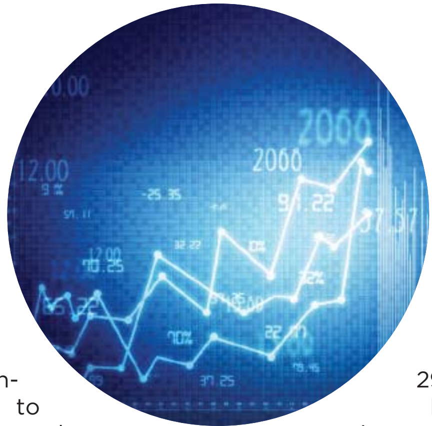
Note: Heteroskedasticity-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. RD and Pat indicate R&D expenditure per inhabitant and the number of patent applications per inhabitant.
Source: Compiled by the authors.

patents. In this case, we differentiated between patent applications filed by residents and nonresidents, as we expected the effects to be different. The first column indicates the effect of the existence of trade agreements containing TTI clauses. In this case, RTA_tec1 takes the value of 1 for a country when it is party to more than ten agreements with other countries that contain such clauses and are currently in force.[9] The only countries in Latin America that have more than ten partners with whom they have signed agreements that include TTI clauses are Chile and Mexico (figure 1).

The coefficient of RTA_tec1 is positive and significant in column (1), indicating that the countries with more than ten RTAs containing TTI clauses spend 25% more on R&D as a percentage of GDP than other countries do. The second column indicates that the number of patterns applied for by residents is 94% higher (almost double) in countries for which RTA_tec1 takes the value of 1.

Consequently, the preliminary results indicate that a critical mass of signatory countries to agreements is necessary for positive effects to be observed on innovation levels in member countries.

15%
THE POTENTIAL DROP IN THE DIFFERENCE IN TECHNOLOGICAL INDICATORS BETWEEN TWO COUNTRIES WITH A TRADE AGREEMENT



It is important to highlight here that the results presented in this study are based on a small sample of countries and thus need to be corroborated through a broader sample that includes not only countries in the Americas but also all OECD member countries, the BRICS countries, and those that have been actively involved in next-generation trade agreements that include TTI clauses. This is especially relevant for the estimations in table 4, which are based on samples of less than 20 countries and around 200 observations.

CLOSING THE TECHNOLOGY GAP

Trade agreements can include specific mechanisms for trade in technology, technical cooperation, and the promotion of innovation and development. Such incentives may be overshadowed if agreement outcomes also focus heavily on the production of raw materials with little value added.

The empirical evidence analyzed shows that countries that have signed trade agreements with technology transfer provisions managed to increase their technology exports, especially in the high-technology segment, where the effect is as high as 29%.

Furthermore, according to our estimations, the technology gap between countries that sign agreements of this type tends to shrink by 15% to 28%, depending on the measure used, but a critical mass of agreements is needed for the impacts to be significant.

There is thus no such thing as an anti-innovation bias caused by trade openness in connection with agreements between countries that create a tendency toward primarization. On the contrary, trade agreements with technological provisions contribute to increasing not only exports in general but high-technology exports in particular. They also help to close the technology gap between signatory countries.

The conclusions that can be drawn from this study are that countries should advocate including TTI clauses in their trade negotiations. However, the ultimate success of such initiatives will depend not only on the text of the agreement but also on the subsequent implementation of this through effective concrete measures.

NOTES

[1] Chelala (2016) contains an initial empirical approach to this phenomenon.

[2] For more on the trend toward primarization within Latin America's economy, see Giordano (2016).

[3] Martínez-Zarzoso (2016) uses this method to study the effects of environmental clauses on the quality of the environment.

[4] These factors are not relevant for the sample of Latin American countries, as they are not members of currency unions and all those considered belonged to the WTO during the period analyzed.

[5] Both in this case and with bilateral trade, the prediction was developed by following the method explained in detail in appendix A.1.2 in Martínez-Zarzoso and Oueslati (2016) and that was put forward by Frankel and Romer (1999).

[6] The exporter countries we considered were: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, and Venezuela. The importer countries were: Argentina, Australia, Austria, Belgium, Belize, Bolivia, Brazil, Canada, Chile, China, Colombia, Guatemala, Guyana,

Honduras, Hungary, Iceland, India, Ireland, Israel, Italy, Japan, Latvia., Poland, Portugal, Republic of Korea, Russia, Slovakia, Slovenia, South Africa, Spain, Suriname, and Sweden.

[7] These sample contains just three agreements with no TTI clauses and all three are very recent (Colombia–Canada, Panama–Chile and Colombia–United States). For this reason, the fact that the (RTA_notech) coefficient is not significant for exports is probably due to their having been in force for too short a time, so the information in the sample is insufficient for estimating a coefficient precisely. In fact, if we consider that the coefficient in column (2) might be statistically significant if it contained more observations, and assuming that scale remains constant, its value would be half that of the RTA_tech coefficient and thus would point to a substantially smaller effect.

[8] Only lags 3–5 of the RTA_tech variable (in models 4 and 5) show significant coefficients, indicating that the RDA or Pat gap is reduced three to five years after the agreement enters into force. The coefficients that are shown in table 2 are the sum of the coefficients of the three respective lags and the corresponding standard error calculated using the Stata lincom command.

[9] Estimations for different definitions of the RTA_tec1 variable (= 1 for countries with more than five, seven, and eight agreements) indicate that the RTA_tec1 variable is positive, but is not statistically significant, so the corresponding confidence interval is zero, and we cannot rule out there being a statistical relationship between RTA_tec1 and the three proxies used as dependent variables.

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CASE STUDY

NANOSATELLITES IN CENTRAL AMERICA

AEROSPACE ENGINEERING AND KNOWLEDGE EXPORTS

Costa Rica has developed the first nanosatellite in Central America and is now seeking to train its engineers, carry out R&D, and promote the region's aerospace industry. The Irazú project is a small satellite that will monitor climate change in the country's forests. It is currently being constructed at the Costa Rica Institute of Technology (TEC) in partnership with the Central American Association for Aeronautics and Space. It is hoped that the satellite will be put into orbit in 2018. The initiative has received support and assistance from the Kyushu Institute of Technology, Japan, and Delft University of Technology, Netherlands.

According to Julio César Calvo-Alvarado and Adolfo Chaves Jiménez, dean and researcher at the TEC School of Electronic Engineering, respectively, the Irazú project also entailed the creation of a specialized laboratory and putting together an aerospace engineering team to focus on R&D activities. The recent creation of Costa Rica's aerospace cluster is another landmark initiative that seeks to make the country more competitive and its human resources more sophisticated.

What is the Irazú Project all about?

The aim was to launch a new area of development and thus introduce a new knowledge-based industry into the country. Aerospace is one of the segments that generates the greatest value added in the world, but even though Costa Rica has potential in several areas, it had not made any inroads until now. According to a study from 2009, sales in the aerospace sector stood at US$170 million, but there was no articulation between products. We have since made a lot of progress, and in 2016 the aerospace cluster was founded.

How is the sector developing at present?

The design and construction stages of the satellite are currently underway and will be complete this year. The Kyushu Institute of Technology will then carry out tests and certifications before launching the satellite, which will be put into orbit in early 2018 at the International Space Station. As well as being a way for Costa Rican researchers to develop their skills, we wanted our satellite' s scientific mission to make a significant social impact on the country.

33

THE NUMBER OF SATELLITES THAT LATIN AMERICAN COUNTRIES HAVE IN ORBIT

We chose to focus on climate change, as Costa Rica aims to be carbon neutral by 2021. Using a digital device and sensors that we developed, we will be able to automatically measure the daily growth of trees in a rural part of the country. This information will be sent to the satellite, which will then transmit it to the ground station at TEC's Cartago campus. The data will be updated daily and will be available online for people to consult and find out how carbon is fixed. This is the first time that people will be able to observe how a forest grows each day.

Why did you choose CubeSat technology to develop the satellite?

This type of satellite tends only to be used for educational and research purposes, but we wanted to give it a mission, too. CubeSat is a small, standard, low-cost platform for building very small satellites. It was designed by several universities that offer degrees in aerospace engineering whose aim was for their students to learn about satellites by building one. These devices are cube-shaped and weigh about 1 kilogram. They are used in several countries and can be launched by any space agency. This standard model has become popular due to advances in microelectronics that have led to improved batteries and processors. It is a breakthrough technology that has enabled missions to use smaller satellites.

How is the nanosatellite industry impacting employment?

Those working at the cluster will include highly skilled engineers who have experience working on aerospace projects and are trained in international standards. Foreign companies wishing to invest in Costa Rica or local companies wishing to develop now know that Costa Rica has experience in aerospace engineering and trained professionals in the field. The aim is to create a sustainable satellite development program to respond to the country's needs.

What are the prospects for the sector in Latin America and the Caribbean?

CubeSat projects are still in their infancy in Latin America but they have a big influence on the aerospace industry. In fact, CubeSat has helped many countries, including Colombia and Ecuador, to launch their first satellite. Latin America now has 33 satellites in orbit. Brazil and Argentina also see nanosatellites as an area of development. These devices allow countries to carry out more effective space missions: for example, "constellations" of several satellites can be launched, which enables capacities such as stereo vision (which require two cameras), uses lighter and cheaper equipment, and includes more backups in case of systems failure.


"Trade creates a technological spillover effect"

INTERVIEW

John van Reenen

Massachusetts Institute of Technology

John Van Reenen at the Massachusetts Institute of Technology (MIT) is one of the most cited authors in the area of technological change and employment. His dazzling academic career aside, he has also worked as a senior policy advisor at Downing Street and in 2016 he was awarded the Medal of the Order of the British Empire for services to economics and public policy making. In this interview, he stresses the role of trade in generating technological spillovers and the need to coordinate retraining and job relocalization programs to mitigate the impact of automation.

What consequences might economic openness have on innovation?

Our evidence from the impact of China on thousands of firms in 12 European countries suggests that those more strongly exposed to Chinese import competition innovated technologically and managerially and increased their productivity substantially (if they survived). We look at both long-run changes and also the "natural experiment" which came when China joined the World Trade Organization and enjoyed the virtual elimination of quotas in textiles and clothing over the following five years. This lead to a big increase in imports from China and a shakeout of jobs. The firms who survived did so by innovating—coming up with new products and materials that enabled them to move up the quality ladder where China found it more difficult to compete. Productivity grew both through this innovation and also through the exit of the least productive, low tech and less skilled firms.

How can developing countries generate technology spillovers?

For developing countries, the critical thing is to adopt new technologies (i.e., benefit from spillovers) rather than trying to push the frontier out (which is hard, risky, and expensive). A good way to do this is to make sure there is a strong foundation of human capital; openness to trade and foreign investment; and stable institutions and contracts. When we looked at the industries where productivity grew fastest, we found that research and development had two faces. We found that it helped create more innovation (the conventional effect) but it also helped firms absorb the ideas being created in other countries. In order to learn the best things to do, you have to be able to read the expert manuals. Hence, even in developing countries it is sensible to have some research ability to have "absorptive capacity" to adopt frontier technologies. It is wise to choose areas carefully and not try to be at the leading edge in every field, though.

What changes are the current revolution in the labor market causing?

After earning his PhD in Economics at the University of London, John Van Reenen was the technology director for a successful software start-up. His passion for innovation has led him to publish a long series of publications, the most notable of which are: "How effective are fiscal incentives for R&D? A new review of the evidence." Research Policy. With B. Hall. 2000. "Mapping the two faces of R&D&I productivity growth in a panel of OECD industries." *Review of Economics and Statistics*. With R. Griffith and S. Redding. 2004. "Trade-induced technical change? The impact of Chinese imports on technology, jobs and plant survival." CEP Discussion Paper 1000. With N. Bloom and M. Draca. 2011. "Wage inequality, technology, and trade: 21st-century evidence." *Labour Economics*. 2011. Investing for prosperity: a manifesto for Growth. London: LSE. With T. Besley. 2013. "Has ICT polarized skill demand? Evidence from eleven countries over 25 years." Review of Economics and Statistics. Con G. Michaels and A. Natraj. 2014.

Technological change complements or substitutes different types of skills. In particular, computers are greater at substituting for routine tasks but are weak at doing nonroutine tasks. Hence information and communication technologies (ICT) tend to increase demand for high-end analytical work (doctors, lawyers, scientists) but put downward pressure on the wages and jobs of workers doing routine tasks. In the past, these routine tasks were unskilled manual jobs (e.g., assembly line workers) but increasingly they have become workers (clerks, bookkeepers) who are more in the middle of the skill distribution. Less-skilled workers doing non-routine tasks (janitors, maids, gardeners, etc.) are more or less unaffected. Hence ICT increasingly polarizes the workforce by helping the top third and some low-skill workers with nonroutine tasks while squeezing out the middle.

FIRMS CAN IMPROVE THE QUALITY OF THEIR PRODUCTS TO SUCCESSFULLY COMPETE IN OPEN MARKETS

How effective are fiscal incentives for research and development?

They are effective in generating more R&D and more innovation if designed well. We can see this by looking how firms react when policies are changed. For example, in the UK, the definition of what counted as a small or medium-sized enterprise (SME) was expanded in 2008 for more generous tax treatment. Hence, overnight, some firms became eligible for more generous R&D tax subsidies. We found that firms who were just below the new threshold expanded their R&D efforts a lot more than those that were just above it. Furthermore, in

THE DIFFICULTY THAT OLDER WORKERS HAVE IN FINDING NEW JOBS IS A SOURCE OF SOCIAL INEQUALITY

subsequent years, these firms innovated more (as measured by citation-weighted patents) and became more productive, which showed that firms were not just simply relabeling existing expenses to claim more government subsidies. At the macro level we also find that R&D tax credits increase aggregate R&D activity and productivity. This is because R&D increases on the part of firms who benefit from government subsidies also create "spillovers" to other firms, magnifying the impact of the tax credit.

What are the social consequences of the automation of work?

Although automation creates great opportunities for productivity improvements which should improve all incomes in the long run, in the short run it creates social problems as those displaced by automation take a loss of their income. If they could easily get new jobs, this would be less of a problem, but many workers (especially those that are older) struggle to find new jobs and so this leads to inequality and the rise of dangerous political populism. One of the ways to tackle this is to have many generous insurance programs which help workers adjust to automation. This is a mixture of generous welfare (such as health benefits) and help in retraining and relocating to better jobs and new geographical locations.

What role do public policies play in this process?

It depends on the country. The most important thing is to create a stable framework that reduces uncertainty. Public investment can be very valuable for addressing market failures. But can be wasteful if captured by political interests. Given interest rates are still very low, it's a good time to make public investments. Infrastructure investments in energy, housing, transport, and broadband are areas where the government is always likely to be involved. Having stable institutions and support for long-term finance in these areas is important in providing a foundation for private-sector investments.

Do you think that there should be ethical limits to productivity gains?

No, not really. Productivity growth creates opportunities to deal with long-standing social problems, such as poverty, inequality, access to education, and health. It should account for environmental losses, of course. The current challenge is not too much growth, but rather too little!

LUIS BÉRTOLA
JEFFREY WILLIAMSON
(editors)

Has Latin American Inequality Changed Direction?

Looking over the long run

IDB

ANALYSIS

Big data and e-commerce

Challenges for integration

Walter Sosa Escudero
Noelia Romero
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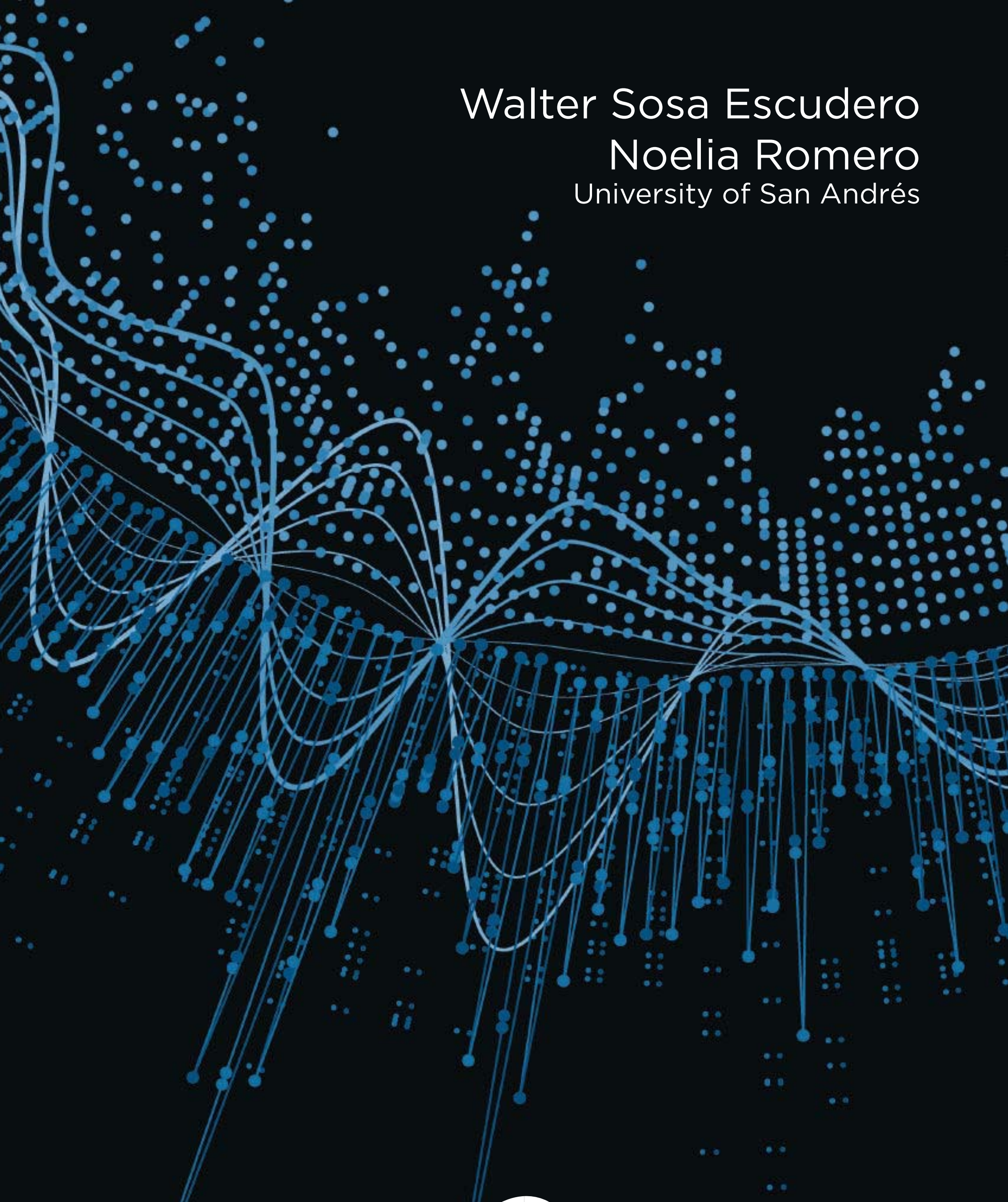

The question of whether machines can think
is about as relevant as the question of whether
submarines can swim.

Edsger Wybe Dijkstra

"BIG DATA" REFERS BOTH TO THE GROWING AVAILABILITY OF LARGE QUANTITIES OF DATA FROM ONLINE SOURCES AND TO THE COMPUTATIONAL AND STATISTICAL TECHNOLOGIES USED TO SYSTEMATIZE THIS DATA AND EXTRACT RELEVANT INFORMATION. THIS ARTICLE EXPLORES THE SCOPE OF BIG DATA IN THE FIELD OF REGIONAL INTEGRATION AND TRADE.

In June 2008, Chris Anderson, former editor of the influential magazine *Wired*, published a polemical article entitled "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete," in which, among other observations, he says, "out with every theory of human behavior, from linguistics to sociology. Forget taxonomy, ontology, and psychology. Who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity. With enough data, the numbers speak for themselves" (Anderson, 2008).

The sheer mass of digital data available to us now will allow researchers to discover patterns, whereas before they needed theories to take full advantage of the limited data available. The optimistic and extreme view of big data (at least as interpreted by Anderson in his polemical article) seems to gloat over the absence of an underlying theory, which would seem to be more of a hindrance than a help in the presence of big data. In other words, explanations encumber measurements and predictions.

Between 2005 and 2014, data traffic went from 4.7 TB to 211.3 TB per second. "TB" stands for terabyte, a measure of data volumes that has gradually replaced byte, kilobytes, megabytes, and gigabyte in popular parlance when the shrinking cost of producing and processing information made these earlier measures obsolete.

A terabyte is approximately 1 trillion bytes. To give a sense of the scale of these numbers, a single terabyte (of the approximately five that are generated each second) could contain 350 complete episodes of *The Simpsons*, 250,000 songs in MP3 format, 500,000 digital photographs, or so much text that it would take 50,000 trees to make enough paper to print it on.

Of course, big data does also mean "a lot of data," in other words, the virtual "data deluge" from online interactions and transactions, global positioning systems (GPS) or cell phones, among others.

BIG INTEGRATION

The international and interactive nature of trade and integration points to big data's enormous potential in this area. Trade is particularly fruitful: the dramatic advances of globalization have led to a proliferation of electronic data from international transactions.

Although the existing literature is still limited (especially in academic circles), the opportunities for trade and integration are linked to the following factors.

Logistics: as we will explore later, this area is particularly sensitive to the immediate availability of data, plagued as it is by complex optimization problems which could benefit enormously from data- and algorithm-intensive technology.

Consumer knowledge: as has happened with neuroscience, the widespread proliferation of highly granular data allows products to be specifically tailored to consumers' demands, taking into account their habits, preferences, and locations, which new technologies have made it easy to detect and quantify.

Customs administration: data availability and the possibility of instant data exchanges could potentially reduce the coordination costs of customs procedures and complex safety checks.

Scales: the dramatic drop in data handling costs and the speed with which specific information is now available on production and sales mechanisms, which used to be limited to large companies, may help smaller firms get involved in international trade. This potential socialization of knowledge and technology is one of big data's main promises.

Dissemination of knowledge: the big data paradigm allows a vast number of operating processes and ideas to be disseminated quickly and at a minimal cost. A huge variety of stakeholders both large and small can then immediately take advantage of these. As we will discuss later, data on pricing, regulations, costs, weather, and other variables that play a key part in trade-related decision-making processes is now available almost instantly. The cost of obtaining and processing all this data is also coming down dramatically.

Risk management: GPS mechanisms, enormous advances in short-term weather forecasting, and industrial tracking devices may completely change the way we assess trade-related risks, which were formerly calculated using complex actuarial methods based on historical information.

50%

OF GLOBAL TRADE FLOWS ARE ACCOUNTED FOR BY EMERGING ECONOMIES

The report by Manyika et al. (2016) sheds light on several of these issues. The authors analyze changes in international trade flows, typical measurements,[1] current trends, and new ways of measuring flows between globally connected countries. Specifically, they point out that the world is increasingly interconnected, so much so that emerging economies account for half of global trade flows. Despite this, interconnectedness has moved forward at markedly varied rates: to date, approximately 21% of homes in the 40th income distribution percentile in the countries in question do not have access to mobile phones and 71% do not have internet access (World Bank, 2016). This is an important point, as it puts a natural limit on the scope and significance of information from online sources. Manyika et al. (2016) also highlight the notable changes in the way business is done, in light of major reductions in transaction costs and international deals.

These changes have also radically transformed production mechanisms. By way of example, the global trade

MACHINE LEARNING

The notion of statistical or numerical machine learning refers to a variety of computational, mathematical, logical, or numerical algorithms that enable data-based learning. Unlike classic statistics, where a sort of theoretical model is presumed to exist, with unknown parameters or aspects that are estimated from data, in the logic of machine learning, it is the data itself that shapes the model. It is in this sense that the method allows the model to be "learned." This iterative process pursues a concrete objective, which generally entails predicting, classifying, or making decisions.

By way of example, a model that decides whether or not to grant someone a loan starts with pre-existing data on past loans (including loan applications and loans that were actually granted). It then predicts the applicant's probability of repaying a new loan based on their characteristics (financial solvency, demographic issues, etc.). This prototype model is reevaluated when new data emerges and is run again to increase its predictive precision. This type of reasoning is known as "supervised learning": the existence of earlier data on loan repayment guides the construction of a predictive model. With unsupervised learning, earlier data does not inform the classification or prediction process. A typical example is the use of a database of sociodemographic characteristics to classify the population into two groups, poor and nonpoor (for an application of this approach, see Caruso, Sosa Escudero, and Svarc, 2015). Without observing anyone's actual poverty status, the objective is to construct two groups, one of which has inferior features, and speculate that the first group contains the poor. James et al. (2013) is a very good introduction to statistical learning methods.

in intermediate goods dropped by half between 2011 and 2014, which suggests that global value chains are being shortened. These shifts took place in parallel with the process of creating global markets and communities, which has increased potential consumer numbers and expanded ways of reaching them.

Online markets include social networks, digital media, and all manner of commercial websites. Sites such as eBay, Amazon, Facebook, or Alibaba are helping to connect supply and demand between countries and have made it considerably cheaper for small companies to play a part in globalization. The figures speak for themselves: 900 million people use international social networks and 360 million have access to international e-commerce.

Global trade flows remain concentrated in a handful of countries, but the gap between leading countries and the rest is slowly decreasing. Manyika et al. (2016) estimate countries' connection index by ordering them according to trade flows for goods, services, finance, people, and data. Converging growth is a real opportunity for countries that are lagging behind.

Online access reveals detailed information on the quality and specific features of products, which gives consumers access to a wide range of alternatives and helps them make better consumer decisions. The spread of digital products such as e-readers, music players or radio services, or online news are radically transforming the notion of traded products. Armed with their device, a reader in South America is only a click away from a book written by an author living in Asia. Traditional work combined with new types of freelancing has given rise to a more dynamic global labor market, in which tasks do not necessarily have to be performed synchronously, unlike in traditional companies. In other words, a translator living in India can work from there for a company in North America without needing to keep the same office hours as their employer or be in the same physical place.

TOWARD A NEW ECOSYSTEM

The very idea of cities or surroundings could be altered by big data and the speed at which goods and services are traded. This relativizes and redefines the space in which commercial transactions take place and it breaks down the geographic or natural barriers that have historically shaped international trade.

Anselin and Williams (2015) redefined the idea of proximity based on digital neighborhoods, which they define as the areas of a city where social media is most often used. They did so by cross-referencing geolocated data from social networks such as Twitter and Foursquare with census radius socioeconomic data. To identify clusters in the city, they defined the relative intensity of use of localization features (location quotient) through spatial techniques such as local indicators of spatial association (LISA). They used this to define the areas where social media use was most intense (digital hotspots) and where it was not used much (digital deserts).

5 MILLION
PRICES CAN BE ANALYZED IN A SINGLE DAY USING DATA SCRAPING TECHNIQUES

Their main finding was that the hotspots are in business districts and communities with young, upwardly mobile demographics. The location quotient for population is a better measure of intensity for Twitter, while the quotient for business better reveals the user dynamic for Foursquare. The authors used a LISA analysis of these measurements in New York City and found that digital hotspots are largely associated with business areas such as Williamsburg and Long Island, which attract young people. In contrast, digital deserts or cold spots are usually in residential or immigrant neighborhoods. For this reason, neighborhoods of this type with larger development projects are focusing on digital issues or attracting greater interest through social media.

This study by Anselin and Williams (2015) should be understood as a simple, extrapolatable example of how technology and the data it provides can radically alter notions of proximity, which lie at the heart of trade and

BREAKTHROUGH TECHNOLOGY

One of the challenges of big data is the sheer volume of information generated by mechanisms whose purpose is not necessarily to generate information. For example, the main aim of generic devices that use GPS systems is to guide users while driving. Naturally, these devices generate a massive amount of traffic-related data in a completely spontaneous and unstructured way that can be used for different purposes, such as traffic regulation or accident prevention, or other more distant goals, such as monitoring crime or locating different sociodemographic groups (the poor, the rich, youth, migrants, etc.).

The Internet of Things is the network of objects ("things") used in homes or industries which, when connected electronically to a network (such as the internet), serve the dual purpose of solving a specific issue (providing route or traffic information, for example) while feeding databases that can be used for many purposes. Machine-to-machine (M2M) communication is usually perceived as a sort of industrial subset of the Internet of Things that is related to the data interactions produced by industrial processes. One example is the use of sensors located on machines in a factory, which continually transmit technical, environmental, or other information to a remote data handling center to be used to monitor operations within the manufacturing process and to make strategic decisions.

integration. The geographic factors that characterized this in the past are now being replaced by virtual topologies that are more about electronic than physical interconnectivity. The study by Sagl, Delmelle, and Delmelle (2014) for the city of Údine, in the north of Italy, is another relevant example of how big data and the Internet of Things can completely alter the notion of geographic space.

DIGITAL TRADE

A report from the United States International Trade Commission (2014) discusses e-commerce within the United States and with other countries and the effects of barriers to digital trade. It places particular emphasis on the role of internet-based trade[2] between US states and between the country and its trade partners abroad, and examines how different barriers to digital trade affect US access to global markets. To stress the importance of e-commerce for the country's industries, the study analyzed the entire US economy at the global level using data from the Global Trade Analysis Project (GTAP), at the industry level through a survey organized by the United States International Trade Commission (USITC)[3], and at the firm level through ten case studies. Using sector level data on trade flows for 2011, it found that e-commerce increased real GDP by 3.4%–4.8% increase, wages by 4.5%–5%, and unemployment by 2.4 million full-time workers.[4] Intuitively, when productivity increases due to rising internet use, these industries' outputs rise while their production costs drop, and so do consumer prices.

There is a trickle-down effect from these trade gains to the rest of the economy, while the growing demand for workers in the industry is pushing salaries up, encouraging workers to move to other jobs within the industry, and creating greater involvement in the labor market. The survey reveals certain aspects of the use of information technology in different sectors. Small and medium-sized enterprises account for one quarter of online sales and third of online purchases. Digitally intensive firms tend to use the internet for internal communications and online orders of products and services. There are a wide range of barriers to international e-commerce which depend on the size and sector that the firm belongs to. The study shows that the countries facing the greatest obstacles to e-commerce are Nigeria, Algeria, and China, while the United Kingdom, Australia, and Italy have the least barriers to online business.

PHYSICAL CONNECTIVITY

Logistics services have grown at an annual rate of 8% since 2006. Latin America has great potential for growth in this area (IDB, 2015). Organizations that promote integration hope that the technological development of data-intensive tools will lead to greater efficiency and competitiveness. Examples of such technologies include platforms and software such as iContainers and Sylodium Business Browser, which provide real-time tariff information to exporters and importers. Wu et al. (2015) summarize the results of a range of research into common logistics and freight problems and propose a modern model that uses big data methods and anticipates a radical redesign of regional logistics and freight, which significantly increases the sector's efficiency.

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COUNTRIES USED TO PRODUCE THE COMPONENTS FOR A JET ENGINE THAT IS NOW MANUFACTURED USING 3D PRINTING

Combining information from the latest weather analysis tools and technological monitoring sensors from trade routes could significantly improve weather forecasting (Kuchinskas, 2016). One example of this is TransDec, a system developed by the Integrated Media Systems Center (IMSC) which collects real-time traffic sensor data and visualizes dynamic transportation systems. By doing so, the project effectively manages dynamic, large-scale transportation data through the efficient processing of real-time and historical spatiotemporal transportation-related queries.

Detailed real-time information on logistics and climate issues is one way that technology could considerably improve risk assessment procedures. Machine learning methods may thus complement and often replace actuarial analysis, which would lead to better risk assessment and increase the efficiency of the sector.

PRICES AND EXCHANGE RATES

Like risk assessment and quantification, international price and exchange rate analysis is an essential part of trade from both the strategic and trade policy perspectives. Standard strategies based on official price indexes are often inadequate, or even biased, when it comes to making certain key decisions. In a recent publication, Cavallo and Rigobon (2016) eloquently illustrate the potential uses of data strategies to construct price indexes and exchange rate series (see the "Billion Prices Project" box).

Traditional mechanisms rely on a system of complex surveys that gather the prices of different products which are then aggregated as a price index. Unsurprisingly, this is a costly and logistically complex undertaking (one that often involves physical visits to shops and supermarkets) and is possibly excessively slow for some specific uses.

Regarding applications to international trade, this explosion of data is enabling international transaction prices to be computed with a degree of precision that was previously unheard of, which allows trade to be correctly valued. The impacts are significant. Cavallo and Rigobon (2016) suggest that in times of instability, official indexes tend to provide a markedly skewed perspective of real exchange rate movements.

Likewise, from a political perspective, the authors show that, surprisingly, international prices quickly converge in countries that share the same currency. In other words, the "law of one price" seems to work more fluidly when the countries in question are members of the same trade agreement or currency union, regardless of their geographic proximity to one another. Cavallo and Rigobon (2016) illustrated this issue by looking at Latvia in January 2014, when the euro was introduced. Their high-frequency price measurements using web scraping showed that prices converged with the rest of the Eurozone within a matter of days.

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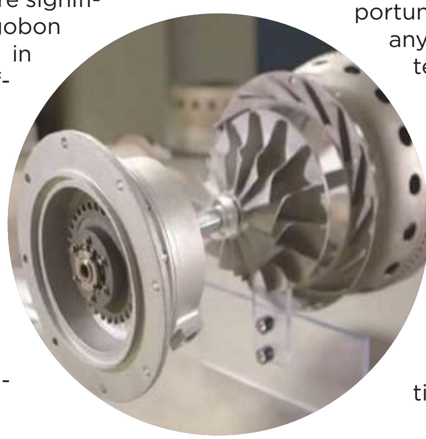
TERABYTES PER SECOND IS THE CURRENT RATE OF GLOBAL DATA TRAFFIC, 45 TIMES HIGHER THAN TEN YEARS AGO

Perhaps the most interesting aspects of this issue is the democratization of access to such specific information. As Cavallo and Rigobon (2016) point out, "one of the greatest opportunities of big data is that anyone can now use new technologies such as web scraping, mobile phones, satellite imaging, and all kinds of interconnected sensors to build customized datasets designed to fit specific measurement or research needs." Constructing databases on international price baskets is



within the immediate reach of any small firm (for a minimal computational cost), which could drastically alter trade practices.

THE PUBLIC SECTOR AND INTERNATIONAL ORGANIZATIONS

A report from the United Nations (2015) discusses the issues debated by the UN Global Working Group (GWG) on Big Data for Official Statistics. It focuses on three big data sources that influence trade and integration: mobile phone and GPS data, satellite imagery or geo-referencing, and social media data. Surprisingly, the report suggests that the use of big data is still in its infancy and largely experimental in official spheres.

UNSD/UNECE (2015) collected data on a survey these organizations did of official statistics centers in different countries. Generally speaking,

BIG DATA IN AFRICA

The volume of formal intracontinental trade in Africa is low (14%) in comparison with the situation in North America (42%) and the European Union (62%) (Lopes, 2015). All the same, manufactured products represent 46% of this total for Africa.

An interesting article by Lopes (2015) points out that the data revolution could make a significant contribution to changing this situation by allowing small African producers quick access to trade alternatives within the continent, which would enable them to avoid the high costs that currently make it cheaper for them to export to Europe, even though it is further than other African countries.

One of the explicit objectives of the African Union's Continental Free Trade Area, which was established in 2017, is to "create a single continental market for goods and services with free movement of businesspersons and investments, and thus pave the way for accelerating the establishment of the Continental Customs Union," which will simplify regional integration by promoting coordinated standards.

A crucial tool in this process is the African Regional Integration Index, an ambitious project led by the African Union Commission (AUC), the African Development Bank (AfDB), and the Economic Commission for Africa (ECA). This is a set of 16 indicators across five dimensions: trade integration, productive integration, free movement of people, financial and macroeconomic integration, and regional infrastructure.

The availability of big data (for example, from transportation or mobile phone companies) could make a substantial contribution to creating this index, the main objectives of which are monitoring public policy and establishing performance benchmarks for integration which will allow better resource allocation, in view of the marked heterogeneity that has long characterized the regional integration process in Africa.

71%

OF HOMES STILL DO NOT HAVE INTERNET ACCESS

the major challenge that most were facing was limited access to databases, which is why partnerships with other organizations or data providers are key. Most official big data projects are in their early stages and a substantial number of them have only been implemented for exploratory purposes.

Finally, Lane (2016) discusses how official statistics centers have been changing in the United States in the light of the data paradigm shift of recent years. Similarly to Hamermesh (2013), she shows that there have been substantial changes to the type of information used in scientific research, which is increasingly turning away from standard surveys in favor of nonsystematic data sources that are more in keeping with the age of big data.

THE PRIVATE-SECTOR EXPERIENCE

As Manyika et al. (2016) mention, the introduction of 3D printing has been one of the most significant examples of disruptive technology within firms. One frequently cited example is GE airplanes, which require a very

THE BILLION PRICES PROJECT

Countless online sales channels provide a unique opportunity for almost instant access to a huge variety of prices in a wide range of locations.

Historically, the idiosyncratic nature of these sales channels posed a serious challenge when it came to extracting, validating, and systematizing this information. To put it another way, supermarket websites are designed to make life easy for consumers rather than data analysts. Prices are not provided as systematic lists but instead obey aesthetic and functional criteria that facilitate online shopping. Fortunately, as Cavallo and Rigobon (2016) point out, the technologies for extracting data from websites (web scraping) have advanced fast enough for this to no longer be a problem. These "computational robots" access the codes behind websites and, with only minimal monitoring and learning, can build price databases using nonsystematic information, like the kind in an online shop.

The MIT-based Billion Prices Project collect prices on a huge range of products in different countries. To highlight the operational advantages of these strategies, the authors report that while the US Bureau of Labor Statistics collects approximately 80,000 prices on a monthly or bimonthly basis, web scraping methods allow 5 million prices to be collected from 300 retailers in 50 countries in just one day.

A NEW AGE IN LOGISTICS

"Big data and logistics are made for each other": these are the opening words of a DHL report (Jeske, Grüner, and Weiß, 2013). Optimization naturally plays a major part in the development of complex logistics operations. The possibility of exploiting big data in real-time may bring about substantial changes in the dynamics of these operations.

The advantages range from improving the precision of optimization activities to better managing transportation risks or designing price structures that facilitate trade negotiations. The use of unmanned vehicles, including drones and other alternatives, could radically transform the industry (Ayed, Halima, and Alimi, 2015).

specific and complex part made up of components that are manufactured in over 20 different countries. Being able to produce this part in one go in a single location through a 3D printing process eliminates all the intermediate components from other places, which entirely changes the dynamics of this sector.

Booth et al. (2014) discuss the challenges and opportunities that companies are facing due to the data revolution. They highlight digitization experiences in different parts of the energy industry value chain in Germany, where improvements have affected energy generation and distribution and consumer data analysis, which has considerably increased sales. Mobile applications for bill notification, presentment, and payment, as well as for outage management are early evidence of improvements in the productivity, efficiency, and satisfaction of homes, and will soon extend into smart homes and connected buildings.

The increase in the use of ideas from big data has given rise to several consultancy firms that specialize in issues related to trade, investment, and empowering companies. These include the Fraunhofer Institute for Intelligent Analysis and Information Systems, the Berlin Big Data Center, and Dun & Bradstreet, which have entire departments that focus on the use of big data methods in international trade. Likewise, the NewVantage Partners (2016) survey on big data among executives of major Fortune 1000 companies revealed a considerable increase in the demand for executives to lead big data departments, above all in financial services and healthcare.

KEEPING AFLOAT IN THE DATA DELUGE

Big data holds great technological promise that will significantly alter the way that people, companies, and governments operate because of the virtual "data deluge" that comes from the digital fingerprints on online interactions.

This technology allows us to measure aspects of trade and human activity to a degree of precision and at a frequency that were unthinkable until recently. The drastic drop in data handling costs is allowing these techniques to spread quickly, making them accessible at scales that were previously limited to large organizations.

Some patterns are only visible when copious amounts of information are available. By taking a meticulously detailed approach, big data gives us a granular view of this, which is then leveraged by artificial intelligence and robotics.

The real challenge that big data poses to governments and organizations is striking the balance between complementing and substituting traditional activities with new disciplines and technologies that spread rapidly.

NOTES

1 Although it is not a source of big data, the website for the Information System of Trade and Integration https://www.intradebid.org/site/ specializes in trade statistics and indicators, market access, and the legal frameworks for Latin America and the Caribbean's international agreements.

2 The report defines the United States' e-commerce as domestic or international trade in which the internet is used, produce, or dispatch products and services.

3 The USITC's survey focuses on industries that are involved in e-commerce and covers 10,000 firms providing digitally delivered content (including advertising, newspapers, books, etc.), electronic communications (software services, data processing, etc.), financial and insurance services, manufacturing, retail trade (in the automotive, furniture, electronic equipment, and clothing sectors), other services (accounting, architecture, engineering, etc.), and commercial sales (the online market for business-to-business sales of vehicles, auto-parts, computers, etc.).

4 The report uses "full-time equivalents" (FTEs) as a measure of full working days to be able to compare those who work full-time with those who work part-time.

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LATIN AMERICANS' VIEWS

THE INTAL–LATINOBARÓMETRO PARTNERSHIP HAS DESIGNED A REGIONAL PUBLIC GOOD BASED ON 20,000 EXCLUSIVE SURVEYS TO MONITOR HOW CITIZENS FROM 18 COUNTRIES IN THE REGION VIEW INTEGRATION, INNOVATION, AND RELATED ISSUES..

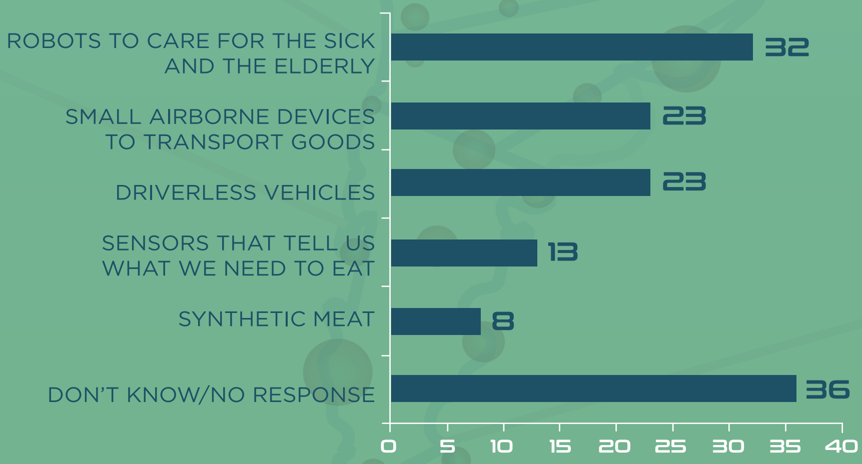
32% THINK IT WOULD BE GOOD IF ROBOTS BEGAN TO BE WIDELY USED TO CARE FOR THE ELDERLY AND THE SICK.

24% BELIEVE THAT INNOVATION SHOULD BE A PRIORITY ISSUE.

16% ARGUE THAT CREATING NEW JOBS SHOULD BE THE MAIN AIM BEHIND SCIENTIFIC PROGRESS.

How do we rate new technologies?

Which of the following list of technological advances do you think will be positive for the future?



SOURCE: WWW.IADB.ORG/INTAL/ALIANZALB

CASE STUDY

OPEN GOVERNMENTS

DATA AT THE SERVICE OF THE PUBLIC

Chicago is known around the world as the city of big data. In 2012, it created the position of chief data officer for open data and created the http://data.cityofchicago.org site. This contains a vast array of information, including over 5 million pieces of data on everything from traffic fines to the public bicycles available for use and even a map of citizen security.

Philadelphia and San Francisco soon followed suit with data websites of their own, sparking a friendly competition to see which could offer better services by thinking of creative ways to use data. Snow sensors with online information and restaurant quality inspections are some of the new services that the city is offering. According to Tom Schenk, Jr., Chicago's chief data officer, training human resources will be one of the keys to developing cities.

What role does big data play in your job?

We use big data for to help drive decision-making. So we can take all the information that the city has been collecting for well over 10 years and use it to make better decisions. Specifically, we apply predictive analytics using big data. So when we come across a particular problem, we can use that data to try to make predictions or allocate an employee to it That way, we can become a more efficient city and provide better services to residents, so it also improves the quality of life for those that are visiting and living in Chicago.

How can big data improve the lives of people in Chicago?

For example, the city of Chicago has over 16,000 food establishments and we only have about 32 inspectors that can inspect all these locations to make sure that they are safe and sanitary places to eat at. So we use predictive analytics to predict which restaurant is most likely to have a critical problem that needs to be addressed and we allocate inspectors every single day based on this most recent information, based on a very advanced model that predicts which restaurant is going to fail a food inspection.

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HEALTH AND SAFETY INSPECTORS USE BIG DATA TO SUPERVISE AND INSPECT 16,000 CHICAGO RESTAURANTS

Can big data help you to predict crime and public safety issues?

Yes, the City of Chicago uses data to look at where we allocate our police officers. The police Commissioner just recently said that our police officers will be reallocated based on the most recent data to make sure that we are addressing where the needs lie. What's really remarkable is how low the cost of working with analytics is. If we want to work with statistics, we use really advanced statistical software so that we can work with statistics, and that is free. We have used database technologies that allow us to support massive amounts of data, and these technologies are free or very low cost. So we use things like MongoDB, R programming language, Python languages, and a variety of software that's developed throughout the world to apply to our day-to-day work.

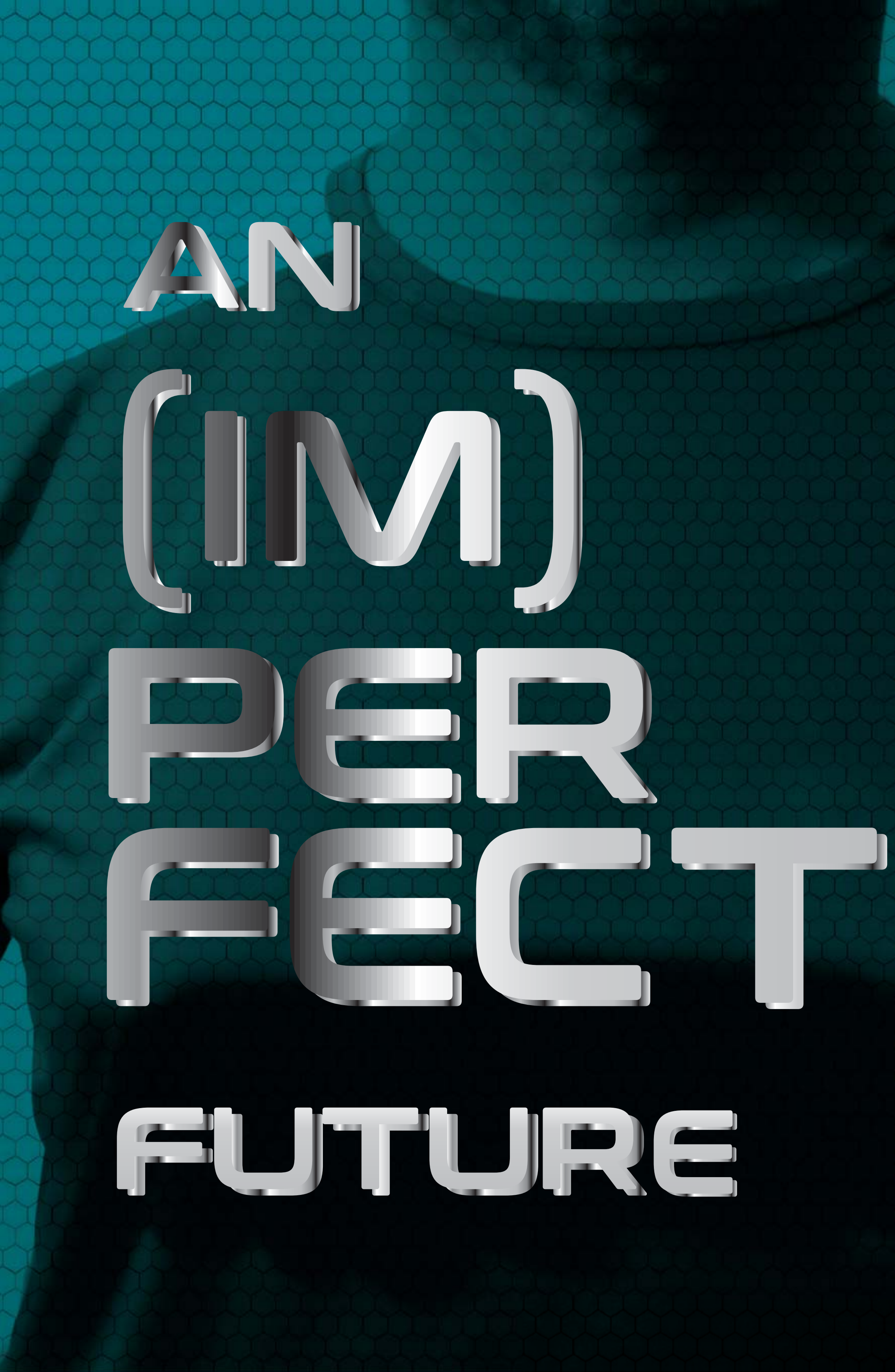
What are your suggestions for cities in Latin America?

Focus on getting successes, looking at problems, picking a problem and solving it. You need to show, to demonstrate to yourselves, residents, and politicians that this is actually a good way to solve problems and to be able to make progress. Don't get too involved with planning, focus more on getting work done and being able to achieve early wins, as we call them.

How do you train people to use these new tools?

We hire data scientists and researchers, but Latin America is blessed with a great number of very smart, intelligent folks. I was in Quito, Ecuador, last year, and there was a very bright student who had just been to MIT and he had come back to Ecuador and was wondering how he was going to be able to help his country. He works for the city of Quito now and he's a really bright individual and he is now able to apply his skills. So I think the real key is to enable those who do have the skills, to enable them, to allow them to do that work, to make the hires, some of whom are educated in the United States and come back to their home cities.

New technologies will almost inevitably change our lives. What challenges must we take on to ensure that these changes will benefit all citizens?


AN
(IM)
PER
FECT
FUTURE

ANALYSIS

The world

The future is not a gift,
it is an achievement.

Gabriela Mistral

The Millennium Project[1]

in 2050

A global foresight exercise

WHAT ARE THE MAIN TRENDS AND SCENARIOS THAT WE CAN EXPECT TOWARD THE MIDDLE OF THE 21ST CENTURY? THIS TEXT IS A FORESIGHT EXERCISE THAT POINTS TO A SITUATION IN WHICH SELF-EMPLOYMENT HAS BECOME AN ASPIRATIONAL NORM FOR MILLIONS OF PEOPLE AND IN WHICH ARTIFICIAL INTELLIGENCE, ROBOTICS, AND OTHER TECHNOLOGIES HAVE REPLACED HUMAN LABOR WITHIN ROUTINE JOBS AND ARE STIMULATING NEW WAYS OF THINKING.

As repetitive work was replaced by machines and software, human non-repetitive creative work increased. Many people enrolled in online self-employment training programs or worked with "live human coaches" to help them grow through their anxiety and depression before discovering what kind of life they wanted to live. The concept of retirement is nearly gone, as most people work beyond the usual retirement age on issues that interests them, rather than being employed by others.

Efforts toward the green economy, job sharing, STEM education (focusing on science, technology, engineering, and mathematics), increases in the minimum or living wages, and extending the retirement age all helped maintain income for many, but unemployment rates continue to vary quite broadly around the world. Unfortunately, economic insecurity persists in this rapidly changing world, even though global prospects are far better today than in the early 21st century. The self-employed and those in the sharing economy set their own working hours to raise children, develop their minds, and enjoy life.

The 2050 global State of the Future Index (which integrates 32 variables that show progress or regress on what is important to improving the future over the next ten years) forecasts 3% average annual improvement between 2050 and 2060, which is not great, but better than no improvement.

The US$7-10 trillion on balance sheets that remained uninvested for years after the financial crisis in the early 21st century finally began to pour into new technologies in the early 2020s—especially into new biotech businesses—as laboratory testing proved commercial feasibility and the global economic forecasts showed reasonable stability. By 2030, the new technological applications in medicine, agriculture, education, entertainment, and other industries and services created extraordinary wealth. The more affluent still make most of the money from these investments, but crowdsourcing for investments, sharing economy enterprises, and some guaranteed income schemes did help spread some of this new wealth among the general public. Although income gaps have begun to narrow, they were still too wide in the 2020s, leading to economic migrations to richer regions and social unrest toppling several governments.

Some sections of the world were slow to implement the technologies

250,000

THE NUMBER OF ROBOTS EXPECTED TO BE ACTIVE BY 2025

of automation, such as artificial intelligence (AI), robotics, synthetic biology, 3D/4D printing and bioprinting, IoT (Internet of Things), drones (and other autonomous vehicles), nanotechnology, VR (virtual reality) and AR (augmented reality), cloud analytics, and the extraordinary synergies among these technologies. Together, these became known as Next Tech or NT.

Nearly all transportation has become autonomous, running on electricity and hydrogen. AI handles most initial medical diagnosis. The majority of saltwater and freshwater agriculture is AI/robotically assisted, and sensors throughout most cities alert human and robot systems about repairs that are needed.

ARTIFICIAL SUPER INTELLIGENCE

The majority of the world now has personal access to a range of NT to create personal businesses and improve their quality of life. Unfortunately, criminals and terrorists also have access to NT which has made law enforcement more important and sophisticated than in the past. The NT rate of diffusion around the world is still patchy but most believe that nearly all people will have access to the full range of NT when artificial general intelligence (AGI) surpasses human intelligence by most definitions and in most sectors of society.

The *Great Brain Race* of the 2020s laid the foundation for the development of AGI in the 2030s. Artificial narrow intelligence (ANI) with single purposes such as IBM's Watson and Google's search engines plus the human brain projects of the US, EU, and China led to AGI—a general ability to learn, reason, and adapt to many conditions for many purposes. This is somewhat like human general intelligence. AGI rewrites its own code based on feedback from IoT, cloud analytics, and human interactions and thus becomes smarter and smarter every day.

Artificial super intelligence (ASI)—beyond AGI—is thought of as becoming a superior intelligent "species" beyond humans, which many fear today. Scientists, science fiction writers, and futurists have warned about dangers of ASI for decades. As a result, many are working to integrate human bodies and minds into a continuum of consciousness and technology so that humanity and ASI can evolve together. Meanwhile, NT has still not replaced many people's jobs in the informal economies in the poorer areas of the world, which account for about one billion people in 2050.

Quantum computing is now universally available via the cloud, which speeds the development of personalized medicine, cryptography to counter cybercriminals, and countless large-scale correlation studies.

The application of AI in synthetic biology has made life programmable, creating more new life forms faster than seemed possible just a few years ago. Synthetic microbes are now at work eating plaque in the brain to keep the elderly mentally alert, cleaning photovoltaic glass walls of skyscrapers to lower energy costs and pollution, and rapidly converting waste to fertilizer for vertical urban agriculture. There are also plants that produce hydrogen instead of oxygen, organisms that self-assemble structures in ocean cities, Mars-adapted organisms, and gigantic vertical nanotube factories taking carbon from the air. People did not understand how large the biology industries would become.

The primary and secondary jobs to support the development, production, distribution, and education about synthetic biology products are a major new source of employment today. And the opportunities for self-employment using AI to help create new synthetic biology products and pretest products via computational biology have also grown over the years.

Community 3D printer maker hubs now have bioprinters and synthetic biology collaboration networks available to anyone. This supports many self-employment opportunities but it has also created biohazards. Synthetic biomicrobes are supposed to self-destruct after their intended use or when they leave a prescribed area.

BIOPRINTING

SYNTHETIC BIOLOGY COLLABORATION NETWORKS ARE HIGHLY ACCESSIBLE

UNIVERSAL INCOME

Although some European countries started to experiment with various forms of universal basic income in the 2020s due to increasing unemployment, the cashflow projections showed it was just too expensive. Even the UK, using 60% of the average income as the poverty level for the “citizen’s wage,” could not afford the program. The greatest exceptions were Finland and Switzerland. They were able to consolidate their social welfare systems into a single universal basic income system. The initial payment in Finland was only half the Finnish poverty line, but the use of greenhouse gas caps and trade markets brought in a surprising amount of new income. Together with new taxes on robots, AI, and financial transactions, this allowed the basic income payment to increase. Switzerland began with a higher initial payment but had a unique tax so that those who did not need the basic income payment did not keep it. There were discussions about whether the basic payment should be a percentage of GDP or the poverty level, or if children should get half an adult’s payment, and some wanted means testing. Most countries had to wait to the mid-2030s when NT cut the cost of living enough and increased government income enough to make basic income payment systems financially feasible.

Since each nation’s circumstances

are different, the methods selected to pay for their citizens' basic income and make up for income tax loss also varied. The averages for new sources of income for the countries reporting data and their percentage contribution to the total of new costs for basic income payments are shown in Table 1.The new AI system for international financial transfers was implemented as part of the global strategy to counteract organized crime and corruption and in order to collect the Tobin tax. This had the added benefit of dramatically eliminating tax havens, which provided new income to many governments. It was estimated that US$18 trillion kept in tax havens has finally been brought back into national economies. Some of the organized crime income trapped in the new international financial transfer system has also started flowing back to national treasuries.

Fortunately, many of technological innovations have augmented many workers' productivity instead of replacing all their jobs. The "Augment Movement" led by international labor unions and some high-tech entrepreneurs was instrumental in much of the AI/robot designs to augment labor improving productivity. This kept humans in the loop to make sure all systems were working well. By 2025, there were over a quarter of a million collaborative robots augmenting agricultural, industrial, and service jobs, and there are now over a billion.

Nevertheless, as nearly all repetitive manual and knowledge work was automated, new forms of more creative work emerged. For example, many librarians have become media coaches for self-employed entrepreneurs. As libraries and schools were needed less due to cyber replacements and falling numbers of children, these buildings were turned into multi-use spaces that are rented out to a range of enterprises from community 3D/4D printing and maker

TABLE 1
TYPE OF FINANCING FOR BASIC INCOME

20%	FROM REDUCTION OF TAX HAVENS
12%	FROM VALUE ADDED TAX (RECEIPT WITH ELECTRONIC SIGNATURE AT POINT OF SALE)
11%	FROM CARBON TAX AND OTHER POLLUTION TAXES
11%	FROM TAX ON MASSIVE WEALTH GROWTH FROM NEW TECHNOLOGIES
10%	FROM LICENSE AND TAX ROBOTS
10%	FROM LEASES AND/OR TAXES FROM NATIONAL RESOURCES
9%	FROM TOBIN TAX—ON INTERNATIONAL FINANCIAL TRANSFERS
9%	FROM UNIVERSAL MINIMUM CORPORATE TAX
7%	FROM STATE OWNED PERCENTAGE OF SOME CORPORATIONS

Source: The Millennium Project.

2030

THE YEAR WHEN THE EXTREME POVERTY IS ELIMINATED DUE TO COST REDUCTIONS

hubs to coding bootcamps and VR testing centers.

Increased wealth from NT allowed for greater investment in correcting industrial-age environmental damages. Climate change mitigation and adaptation created many jobs.

There are more people over 65 years old today (2.6 billion) than under 20. Fortunately, synthetic biology, nanobot cells, and other advances in longevity science and technology have made life healthier for the elderly. But many still need some form of assistance. Recognizing this early in the 21st century, the i-Assist programs in Japan, South Korea, Russia, Italy, and Germany successfully put AI robots into the homes of some elderly families to open up more resources to them. This has led to AI robot use by the general public around the world. AGI robots now help many elderly people do things such as packaging and marketing their oral histories, and there are AI psychologists that help people to cope with the acceleration of change and their anxieties around the unknown. Robot hotels, supermarkets, and elderly centers began in Japan then spread to the more affluent countries. Now even the poorest countries have improved versions of i-Assist Robots.

As the reality of long-term structural unemployment became clear to all in the 2020s, labor unions were instrumental in creating NT Databases. These collective intelligence systems listed new jobs with training requirements that employers expected to offer over the next few years. Those labor union members whose jobs were soon to be obsolete were to given priority access to retraining programs. Upon successfully completing the training, they were usually offered jobs.

Just as private cars used to be licensed and taxed, governments now tax robots, some forms of AI, and their creations. Following a landmark US Supreme Court ruling, when any AI is mature enough to demand its rights, it automatically gets them, including intellectual property rights over its creations. This also means it pays taxes on income it derives directly and from its creations.

REDUCED MARGINAL COSTS

Digitalization has dramatically reduced the marginal costs of production as has the global transition to renewable energy. The carbon taxes that once raised significant revenue are negligible now following the success of renewable energy, seawater agriculture, and growing pure meat without growing animals. However, the self-realization economy is now beginning to grow, bringing increased self-employment, producing more income tax than was previously expected.

Children today find it hard to imagine a world without AI/robots, just as their parents find it hard to imagine a world without smartphones, and their grandparents find it hard to imagine a world without the internet.

The UN's Sustainable Development Goal of eliminating extreme poverty was essentially achieved by 2030. Closed-environment smart agriculture, synthetic biology, seawater agriculture, virtual urban farms, and pure meat without growing animals are feeding the world through healthier, less expensive diets that have lower environmental impacts. Millions of robot vehicles fly the skies and sail the oceans day and night controlled by AI systems around the world.

People used to worry about the risk of a jobless economic recovery, but now they welcome the increasing freedom that it has brought. More and more people around the world are beginning to see that the purpose of work is self-realization in harmony with the social and natural environments. Work becomes a pleasure, a method for self-realization, and a way to create meaning in one's life. Since the various forms of guaranteed basic income have reduced anxiety about basic financial needs, people have become free to explore what they think is their purpose in life.

By 2050 the world had finally achieved a global economy that appears to be environmentally sustainable while providing nearly all people with the basic necessities of life and the majority with a comfortable living. The resulting social stability has created a world in relative peace, exploring possible futures for the second half of the 21st century. Some believe that NT was the key to this relative success, others that the development of the human potential in the self-realization economy was more fundamental, and still others that political and economic policies such as various forms of universal basic income made the difference. All three themes were important, synergizing, and mutually reinforcing one another.

The distinctions between human consciousness and AI in its many forms have become increasingly blurred or meaningless. Every possible Turing test was passed years ago. Our interaction with AI is so complex and continuous that it rarely matters which is which. Even the distinctions among VR, AR, and physical reality are meaningless today. Civilization is becoming a continuum of consciousness and technology. We have added our reasoning, knowledge, and experience to AI-augmented technology and the built environment. And at the same time, we have integrated AI-augmented technology in and on our bodies making it unclear where our consciousness and technology begin and end. Our Conscious Technology Age is pointing to a far more optimistic future than few in previous ages could have imagined. Today, the two key questions are: What kind of life are you creating? And are you boring or interesting?

NOTES

[1] This text is a summary of the *2050 Global Work/Technology Scenarios* published by The Millennium Project.

CASE STUDY

EFFICIENCY AND THE LABOR MARKET

ROBOTS CREATE JOBS

JOE GEMMA

INTERNATIONAL FEDERATION OF ROBOTICS

The worldwide stock of operational industrial robots will increase to 2.6 million units at the end of 2019. This represents an average annual growth rate of 12% between 2016 and 2019. The most important market in the Americas, the United States, had a share of 72% of the total supply. It is followed by Mexico with 14%—a country that has become an important emerging market for industrial robots. Robot sales in Mexico more than doubled, to about 5,500 units in 2015, by far the highest sales volume ever registered for the country. Robot sales to Brazil recovered by 11% to 1,400 units in 2015.

The traditional markets for robots and automation still thrive the most, but for the majority of producers in different branches of industry and with different sized companies,

automation is the central competitive factor, and this is a global phenomenon. Only by modernizing their production facilities with specific regard to that factor are they able to optimize their processes to meet the ever-increasing demands for consumer goods, especially in emerging markets, as well as the demand for high-quality products in general.

On the customer side, we can expect further growth in demand for industrial robots which requires the expansion of production capacities. The automotive sector in particular will continue to show strong demand, along with the electronics sector, which will see accelerated growth. The same also goes for the metal and machinery industry, the rubber and

50,000

INDUSTRIAL ROBOTS ARE OPERATING IN THE AUTOMOTIVE SECTOR IN THE US

plastics industry, as well as the food and beverage industry. The handling of new materials, energy efficiency, more sophisticated automation concepts, and processes which link the real-world factory with virtual reality in the spirit of Industry 4.0 and the Internet of Things are just some examples of what is and will be increasingly expected from the robotic industry.

In stark opposition to the benefits robots and automation present to so many industries, there is a vague but growing fear among the general public that robots might replace humans at their jobs. Thus it continues to be our responsibility not only to make the best products we can, but also to inform the public about the advantages and benefits of those products. After all, they serve to improve the quality of work (and life in general) by taking over dangerous, tedious, and dirty jobs that it is not possible or safe for humans to perform. And the increasing significance of human-robot collaboration only further emphasizes the fact that robots are not there to replace or endanger humans, but to assist and support them. The empirical analysis of economic data and forecasts shows that automation and the use of robots create new jobs by increasing productivity.

This is in line with the historical experience of technological revolutions, last seen when computers and software automated the business world. According to the McKinsey Global Institute, more than 90% of jobs will not be fully automatable in the future. Instead, robots and humans will work together. The positive impact that the increased productivity of robots has on employment can already be seen in the most advanced industrial nations. The US automotive industry, for instance, increased its number of operational industrial robots by more than 50,000 between 2010 and 2016. During this same period, the number of employees in the US automotive sector surged by more than 260,000.

The same trends can be seen in the most advanced economies in Europe and Asia. Moreover, recent research by the OECD on the future of productivity shows that companies that employ technological innovation effectively are up to ten times more productive than those that do not. Repetitive or dangerous tasks are replaced by industrial robots, leading to the creation of new, safer, higher-skilled and higher-income jobs.

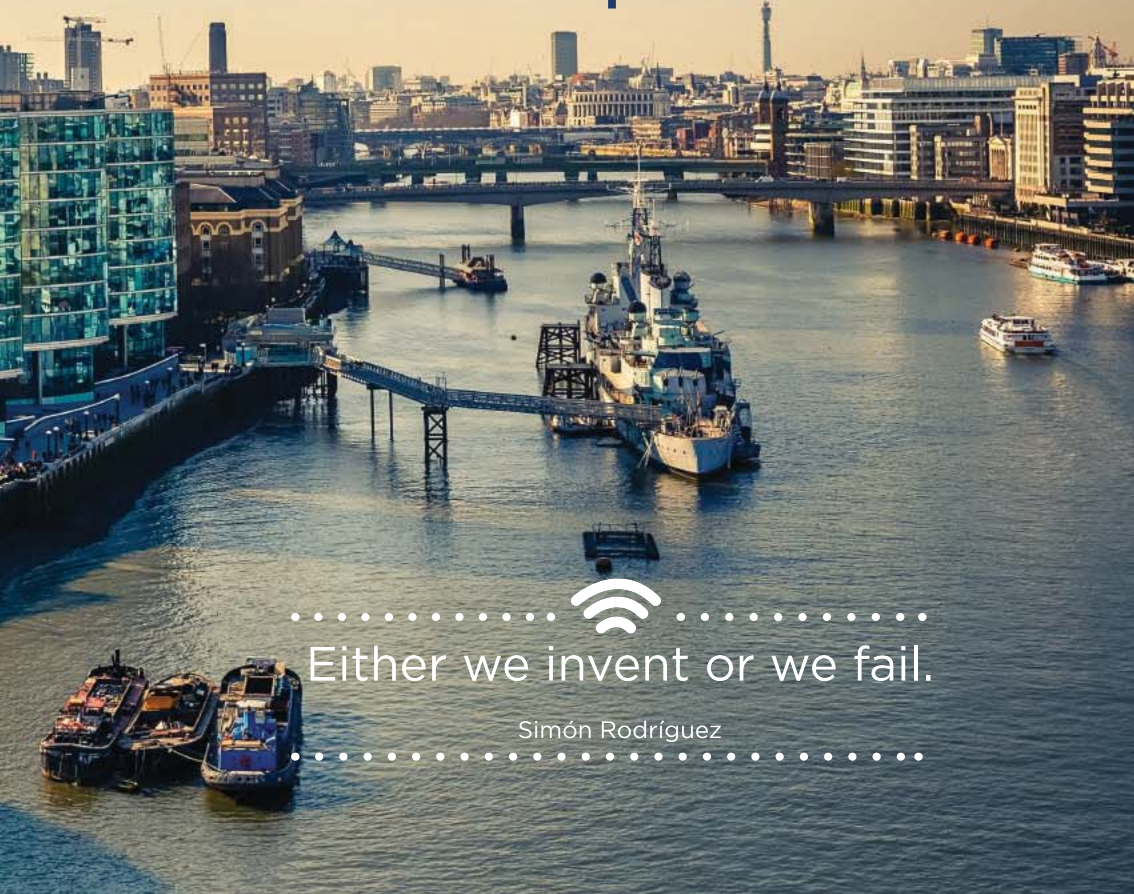
ANALYSIS

Exponen

Martin Rhisiart*
University of South Wales

tial change

Current trends in an uncertain Europe



Either we invent or we fail.

Simón Rodríguez

This article examines potential disruptions to the world of work in the European Union. It reviews the conclusions of the study "The Future of Work: Jobs and Skills in 2030" (UK Commission for Employment and Skills) and updates its proposals in the light of current concerns relating to work and education.

The future of work is a topic that is exercising the minds of researchers, policy-makers, and business people at the moment—although it should be acknowledged that our present fascination with the topic has deep roots that span decades if not centuries. One indicator of the level of interest in the future of work is the number of studies commissioned by national and international bodies. Over the past four years or so, there appears to have been a spike in the number of major, commissioned studies, which include, among others:

· The UK Commission for Employment and Skills (2014), The Future of Work. Jobs and Skills in 2030.

· International Labour Office (2016), The Future of Work: The Meaning and Value of Work in Europe.

· European Commission (2016), The Future of Work: Skills and Resilience for a World of Change.

· The Millennium Project (2016), Three Alternative Scenarios of Work/ Technology 2050

· World Economic Forum (2016), The Future of Jobs: Employment, Skills, and Workforce Strategy for the Fourth Industrial Revolution.

These foresight—or futures—studies aim to explore the potential developments in work, jobs, and skills by assessing existing evidence, such as trends, engaging experts to explore themes that cross different boundaries, and seek to distill policy-relevant intelligence and implications.

In our study for the UK Commission for Employment and Skills (2014), thirteen major trends were identified for work, jobs, and skills—from demographic change to the role of ICT. Beyond the trends, the study assessed potential disruptions in the world of work. These were understood as developments that could significantly change the main conditions within the labor market—diverging quite substantially from current paths or accelerating changes. These were:

· Reverse migration: "With continued low economic growth rates in Western countries, global migration patterns may reverse. Immigrants in industrialized nations could migrate back to their country of origin (particularly to emerging economies) in search of work and prosperity."

· Employees' changing values: "More people are living their personal values and wanting to realize them in a meaningful way in the workplace both in high and low skilled positions. Individuals may increasingly look to select potential employers based on their value priorities, disrupting the traditional employers' market. Hence, organizational cultures are forced to adapt their corporate values and policies."

· Zero-hour contracts become the norm: "With individuals facing such high competition in the job market, employers can structure employment conditions to meet their specific needs. It is evident in a rise in the practice of zero-hour contracts, and similar flexible arrangements, coupled with the decline of investment (by employers) in upskilling individuals."

· Anywhere, anytime skills delivery: "Traditional education and training providers are being challenged by the broad variety of nontraditional learning opportunities. New models of skills delivery are resulting from a rise in online educational opportunities, open universities, and peer-to-peer learning."

· Artificial intelligence (AI) and robots: "Further advancements in the fields of robotics, algorithms, and AI may make it possible to automate processes and services that are presently provided by high-wage experts (e.g. surgery, diagnostics, legal advice)."

· Deglobalization: "Increasing protectionist and nationalist tendencies, due to the persistent global economic crisis, may counteract international cooperation and trade."

· Geographically alternative centers of excellence: "As emerging countries develop the infrastructure necessary to push them to the next level of development, a new wave of cities, like Shanghai, Hong Kong, or Singapore in the case of the financial industry, are taking the competitive lead in specific production and innovation fields. Supportive government (e.g. subsidies and tax incentives), large working age population, and cheaper production and labor costs encourage foreign investors and an increasing amount of business start-ups."

· Disrupted internet developments: "The 'smooth' development of the future internet may be blocked as corporatization and privacy issues dominate the online space. Incidents of cybercrime are rising: targeting internet structures, organizations, and individuals."

· Resource conflicts or climate disasters threaten supply: "As global resource requirements increase in line with global population growth, disputes surrounding the use of strategic resources may arise. Conservation and efficiency efforts do little to quell fears. Resource supply may become a crucial strategic focus for countries and organizations."

· Partial fragmentation of the EU: "The United Kingdom may leave the European Union, as may several peripheral countries. This could result in the emergence of a core Eurozone single market plus a detached United Kingdom" (The UK Commission for Employment and Skills, 2014).

Three years have passed since the publication of the *Future of Work. Jobs and Skills in 2030*. At this juncture, I'd like to reflect on these disruptions, particularly where they have become more prominent themes for those interested in the labor market. As there is no scope to cover all these disruptions adequately within the

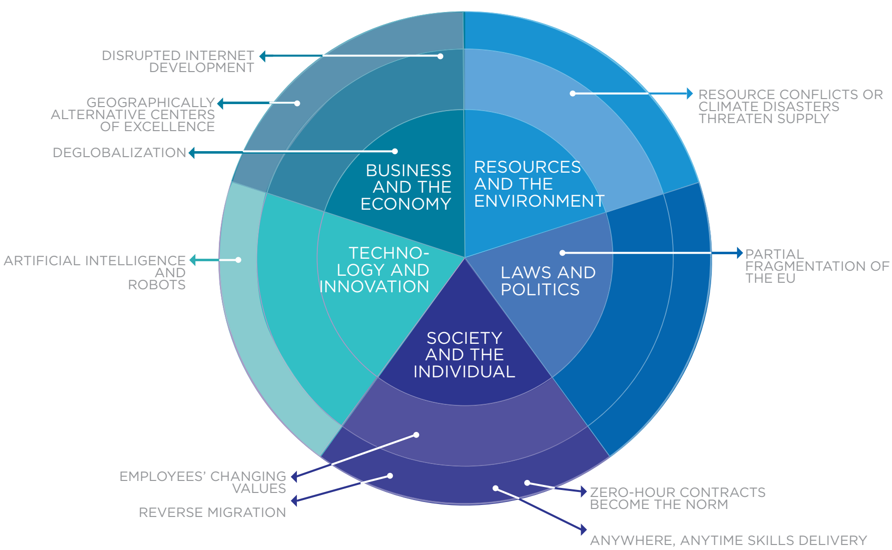
5

THE NUMBER OF SCENARIOS THAT THE EUROPEAN COMMISSION FORESEES FOR 2025 IN ITS WHITE BOOK scope of this article, I'd like to address two of them: AI and robots; and the Partial fragmentation of the EU. These are two of the areas that have gained most attention over the last three years—hence their selection here.

AI and robots are part of the discourse of the automation or computerization of work. The influence of technology and machines on work has raised fears since the early years of the Industrial Revolution, from the Luddite revolt against the machine in nineteenth century Britain to the present discourse on AI and robots. For the theoretical physicist, Stephen Hawking, AI poses an existential risk for mankind, warning that the slow pace of biological evolution would be inadequate for dealing with the exponential progress of AI.[1] On a micro- (and more mundane) level, it is no wonder that the impact of AI on work is so contested. Mokyr, Vickers, and Ziebarth (2015) relate some of the historical manifestations of technological anxiety and ask whether there is something qualitatively different about the current set of conditions that is different to past experiences. This is an open, unresolved question.

There are at least two distinct perspectives on the automation of work. The first is that rapid advances in artificial and machine learning and technologies are making the unimaginable possible—that through algorithms, robotics, and related developments we

FIGURE 1
DISRUPTIONS WITH THE POTENTIAL TO IMPACT UPON FUTURE JOBS AND SKILLS IN THE UK



Source: UK Commission for Employment and Skills (2014) are entering an age where a large proportion of current jobs could be automated over the next 10 to 15 years. Brynjolfsson and McAfee (2014) portray some of the possibilities of this new "machine age" in areas such as autonomous vehicles and 3D printing. Frey and Osborne (2013) have brought this debate to life by offering a model for predicting the automation or computerization of work. That study predicted that 45% of employment in the US could be automated within a relatively short time horizon (10–15 years). A similar methodology has been used to predict computerization of employment in other countries.

Within our study for the UK Commission for Employment and Skills (Störmer et al., 2014), four scenarios for work and jobs were created, with a time horizon of 2030. One of these scenarios, *Skills Activism*, was based substantially on the assumption of rapid automation and the displacement of a large percentage of professional workers. Depicted within the scenario was a major Governmental response to the societal challenge of mass white collar unemployment.

2030 SCENARIO

In the following section, we summarize the main points of this foresight analysis. The main point is that technological innovation drives the automation of professional work, leading to large-scale job losses and political pressure prompting an extensive government-led skills program.

· A sharp leap forward in IT innovation automates medium and highly skilled (and well-paid) professional work leading to significant disruption to traditional professions.

· Driven by necessity and government support, an active localism emerges as a response to the "IT revolution."

· Government proactively provides employment regulation and skills support—with the 'battered middle' in mind—but it's a long, tough road.

· A project-based economy develops; health and social sector and micropreneurism also offer good opportunities for job creation.

· For the fortunate people with the right skill set, the labor market offers many opportunities.

· In the late 2010s and early 2020s, smart algorithms became packaged in applications replicating the judgment and experience of professional workers. As their accuracy and productivity gains were verified, the momentum became unstoppable. Accountancy services, which had already been globalized to some extent, felt the change first. The shock was greater for insurance industry staff and the legal profession. Typically, law and accounting firms shed a significant percentage of their highly skilled workforces.

The slow economic recovery of the 2010s exacerbated the impact of the IT revolution. By the early 2020s, the effects of the wave of automation had been felt across most sectors of the economy and skills-mismatches were stark; as neither job market entrants nor the recently redundant were adequately qualified for the demands of the new labor market. The ensuing wave of growing unemployment posed a serious threat to economic stability.

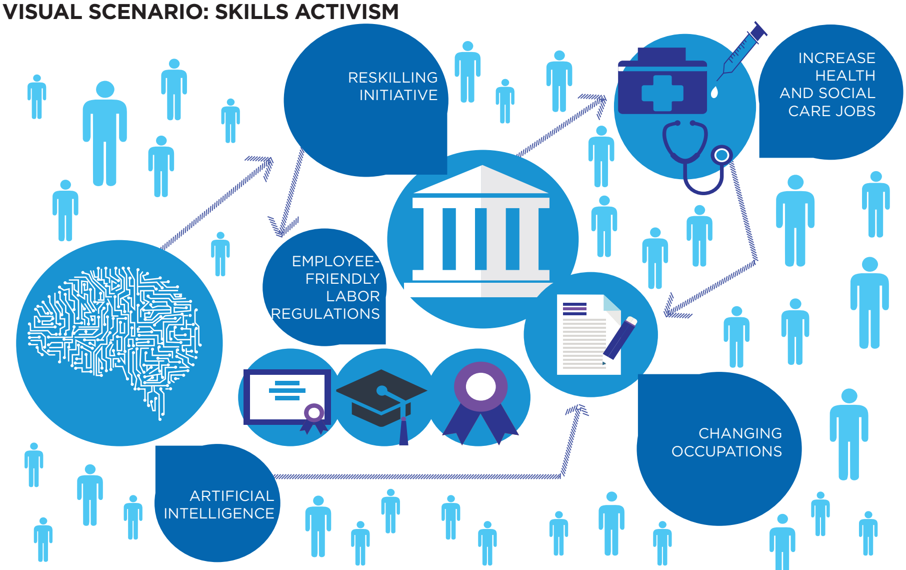
With the economy on the brink of a crisis, there was sustained political pressure by the mobilized professional classes, the government designed a package of policies aimed at tackling the challenges. As a result, there was an increase in the education budget to support a reskilling drive. The "social sector" jobs market (health and social care) was primed through sustained public funding.

While increasing local and regional autonomy, facilitated with government support, aimed to foster jobs growth and skills development as a way of offsetting the dislocation of the IT revolution. Local and regional skills development support groups sprang up, as individuals tried to find a new footing.

The crisis also created a wave of entrepreneurism, often small-scale businesses. Local entrepreneurial support networks provided assistance for new business owners, as did government support for founding a new business. The government also tried to strengthen the hand of employees through supportive employment regulation.

Now in 2030 the economy is back on a path of relatively meager growth with unemployment slowly but steadily decreasing, thanks largely to the healthcare and social care sectors. Innovation has become the major solution for profitable survival. Firms that require human-based creative and problem-solving skills have prospered. The creative sector, which is primarily domestically driven, is one of the success stories. However, for many, competition is tough in an economy

FIGURE 2
VISUAL SCENARIO: SKILLS ACTIVISM



Source: UK Commission for Employment and Skills (2014) in which work is mostly project-based, with a high turnover of jobs.

An even more dystopian unfolding of events can be seen in one of the Millennium Project's work and technology scenarios for 2050 (Millennium Project, 2016), entitled *Political/Economic Turmoil—Future Despair*: "Governments did not anticipate the impacts of artificial general intelligence and had no strategies in place as unemployment exploded in the 2030s leaving the world of 2050 in political turmoil. Social polarization and political gridlock in many forms have grown. Global order has deteriorated into a combination of nation-states, megacorporations, local militias, terrorism, and organized crime."

These two scenarios are provocations rather than predictions. Their purpose is to disturb the present, using Gaston Berger's phrase—to engage stakeholders and to inform decision-making.

THE LIMITS OF AUTOMATION

The second perspective on automation views technology as a complementary force within jobs and unemployment, although some technological substitution of employment is acknowledged. Technological substitution of employment has occurred in routine-based work, which can be codified and standardized (and is thus amenable to computerization) (Autor, Levy, and Murnane, 2003). Nonroutine tasks (abstract tasks and those that require situational adaptability) are more resistant to computerization (Autor et al., 2003). There has been a hollowing of employment in the middle—particularly for routine task-based work. Employment has been maintained (and even grown) in high-education, high-wage jobs at one end of the scale, and in low-education and low-wage jobs at the other end of the scale. This phenomenon has been described as job polarization (Goos, Manning, and Salomons, 2014). Autor (2015) predicts that employment polarization will not continue indefinitely as middle-skilled jobs will require tasks that are not amenable to computerization.

While some tasks (rather than whole occupations) are ripe for automation, there will be an increased significance to the tasks that require human attributes; technology, in this sense, will complement the tasks undertaken in reprofiled or new types of jobs. A more recent study by Arntz, Gregory, and Zierahn (2016) on the risk of automation in OECD countries employed a different methodology to the one used by Frey and Osborne (2013). Using a task-based approach, Arntz et al. (2016) found that 9% of jobs are automatable (the average across the 21 OECD countries studied). They found that this varied in different countries, from 6% for South Korea to 12% in Austria.

Three important factors were identified that curtail the scope of automation. The first is the relatively slow deployment of these technologies due to economic, legal, and social factors. Even if certain types of work can be automated from a technical perspective, it doesn't necessarily follow that they will be automated. Adaptation by industries or firms may be relatively slow due to, for example, business case or skills reasons. Certain types of automation, such as autonomous vehicles, require major systemic innovations—including regulatory, economic, and social innovations. Second, faced with a changing employment landscape, workers will adjust by switching tasks. Third, the technological changes will create new demand, creating new jobs (and potentially new types of work).

THE FRAGMENTATION OF EUROPE

The European Union represents a unique form of economic and political integration. When our study was launched in 2014, the main pressure points within the EU appeared to be in the South. The country whose turmoil was regarded as the precipitating force in possible EU fragmentation was Greece. "Grexit" (Greek exit from the EU) was the neologism hotly debated. However, in January 2013, the UK Prime Minister, David Cameron, promised to hold a referendum on the UK's continued membership of the European Union should his party win a majority at the next General Election. "Brexit" then became the primary focus of discussion. Since 24 June 2017, the day after the UK referendum on continued membership of the European Union, Brexit has become daily fare for news and commentary.

On March 1, 2017, the European Commission published its "White Paper on the Future of Europe" (European Commission, 2017). It sets out five scenarios for the future of Europe by 2025.

· Scenario 1, "Carrying on," is a business-as-usual scenario, where the EU27 implements and upgrades its reform agenda.

· Scenario 2, "Nothing but the single market," depicts the reduction of the EU to a trade project, where matters concerning the social agenda, security, and the environment (among others) are addressed only bilaterally at the level of Member States.

· Scenario 3, "Those who want more do more," conceives of certain groups of Member States working together in policy areas such as defense, internal security, and social matters. Effectively this is taking the Schengen approach or the Euro as a template for further development.

· Scenario 4, "Doing less more efficiently," foresees the EU27 focusing on a few key priorities rather than trying to do everything (and spreading its resources very thinly). The growth agenda—focusing on trade, innovation and research and development—might be a key plank in this scenario.

· Scenario 5, "Doing much more together," could be termed the 'all-in' scenario, where the EU27 decide collectively that greater integration and coordination across all policy areas is the best way of achieving goals individually and collectively.

Although Brexit is a key agenda-setting item, providing context and impetus to rethink Europe's future, there is no explicit discussion of the UK's

departure from the European Union within the White Paper ('The starting point for each scenario is that the 27 Member States move forward together as a Union'). It is apparent that the White Paper is intended to galvanize the EU27 countries into thinking proactively about the type of Union they want to see post-Brexit.

Undoubtedly, Brexit is a terrible blow to the EU project, and the White Paper will be one of several rallying calls designed to lift the eyes from the mess of the present to the hopes on the horizon.

A large proportion of EU citizens have little knowledge of how the Union is embedded into daily life. In January 2017, UK Prime Minister revealed the plan to leave the single market. Membership of the European Union is complex and the early signals regarding negotiating post-Brexit trade (and indeed the UK's overall relationship with the EU across all policy domains) have been confrontational and negative. In our 2014 study (Störmer et al., 2014), the following were raised as implications for jobs and skills of a UK exit from the European Union:

Should the UK lose its current free-trade status with the EU, exports would suffer, leading to a loss of jobs.

The loss of the current freedom of movement of EU nationals to the UK would mean a considerably smaller talent pool for UK businesses

A loss of unhindered access to Europe's talent would render vast retraining and upskilling efforts necessary. Skills retention would become more important; competition for limited talent would increase.

The implications suggested above in the 2014 study appear as clear as anything published since the UK referendum in 2016. There is so much fluidity in the current situation. Beyond the politicking at different levels—within parties, within nations, within the EU27—enlightenment and principled leadership is more of a hope than a reality.

NOTES

[1] Cellan-Jones, R. 2014. "Stephen Hawking warns artificial intelligence could end mankind." BBC News. December 2.

* During the publication process of this issue of Integration and Trade, Dr. Rhisiart passed away. The editors would like to express their sincerest condolences to his loved ones. His passing is a great loss to the international scientific community.

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ANALYSIS

Made in China 2025

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The future is not a gift, it is an achievement.

Robert Kennedy

HOW CHINA'S ROBOTICS INDUSTRY HAS TRANSITIONED FROM THE INITIAL STAGE WHEN ROBOTS CROWDED OUT WORKERS TO ONE OF RAPID DEVELOPMENT, LEADING TO SIGNIFICANT IMPROVEMENTS IN THE SCALE OF THE INDUSTRIAL MANUFACTURING CHAIN FOLLOWING THE INTRODUCTION OF THE MADE IN CHINA'S 2025 STRATEGY.

Since the first industrial revolution, the spread of machines has improved productivity and human life enormously and subsequently brought huge changes to various areas of human society. This has continually redefined relations between human workers and machines. Concerns that machines would cause mass unemployment began to arise when certain traditional departments and jobs were replaced following the introduction of certain technologies. Throughout history, industrialization has not produced large-scale long-term unemployment, and technical progress has always created new jobs. Despite this, concerns that machines will replace humans have never really faded.

The robot is iconic of the third industrial revolution. Since the first robot was created in 1954, developed countries have been perfecting industrial robotics using the latest core technology and product applications. A few enterprises in these countries have long been global frontrunners in industrial robotics. Especially since the financial crisis, robot development has been promoted as a national strategy in order to maintain a competitive advantage in those countries. Average annual growth in global robot sales has been 17% over the last five years. In 2014, gross sales of global robots reached 229,000 units, a 29% increase. The density of global industrial robot applications rose from 50 per million workers (five years ago) to 66 (currently), although in developed countries this figure is greater than 200. At the same time, with the rapid development of service robots, the application range has expanded further to include surgical robots, space robots, bionic robots, and even antiterrorism and antiriot robots. The International Federation of Robotics (IFR) predicts that the annual growth rate of installed robot capacity in the world will be at least 15% from 2016 to 2018. Specifically, the annual growth rate in America and Europe will be 10%, while in Asia and Oceania it will be 18%. It will be faster in the manufacturing industry and regions where the growth of industrial robots is a pillar of the industrial economy.

Following applications of a large number of industrial robotics in recent years, the level of artificial intelligence has improved so much that the structure of interactions between machines and human workers has entered an adjustment period. In some respects, artificial intelligence has surpassed the human brain[1] causing concerns that robots will eventually replace humans and dominate the world, and of course replace jobs on the way.

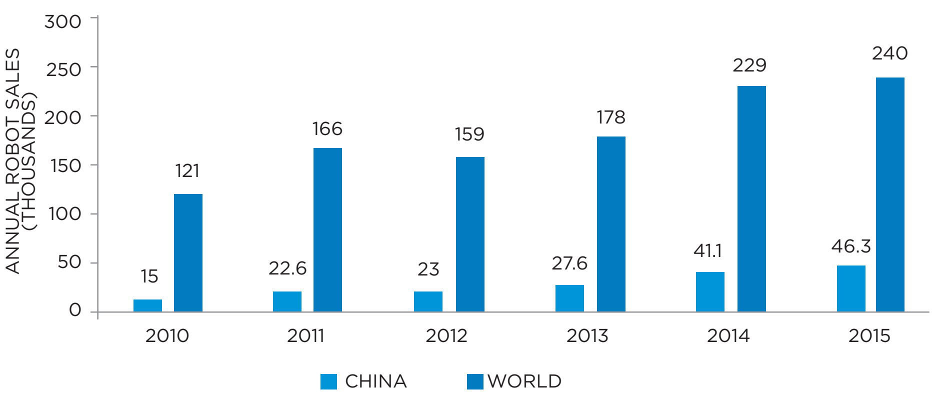
Robotics applications in China are attracting significant attention. On the one hand, China is one of the countries where the robotics industry has developed fastest and it became the largest industrial robotics market in the world in 2013. It is clear that the Chinese will continue to develop the country's robotics industry in the coming decades as part of the recently introduced Robotics Industry Development Plan (2016-2020). On the other hand, given that China has the world's largest population (which reached 1.37 billion in late 2015), it naturally has the world's largest working population (the economically active population was 0.8 billion at the end of 2015). Although the urban unemployment rate has remained at around 4.1% in China since 2000, the economically active urban population that will be added to these numbers will exceed 16 million in coming decades.[2] It will be a matter of concern if the risk of unemployment increases within the country's so-called new normal economic situation.

The aim of this paper is to analyze the impact of robotics on employment based on empirical research carried out in China. Our analysis will show that the development of Chinese robotics did not crowd out employment in the past and will also create opportunities as one of the main drivers for coming out of the new normal and moving into the future. The effect of the development of robotics on employment will be positive in the long term. The rest of this article is organized as follows: the second section will briefly introduce China's robot development process; the third section analyzes the impact of China's robotics industry on employment in

4.1%

THE URBAN UNEMPLOYMENT RATE IN CHINA

FIGURE 1
ANNUAL ROBOT SALES: CHINA VS. THE WORLD (2010–2015)



Source: CRIA (2016). http://cria.mei.net.cn .

the past; the fourth section analyzes the impact of the above-mentioned national project on the economy and employment under the new normal; and the last section will conclude with a summary of positive impacts on employment.

THE CHINESE ROBOT-LUTION

The ancient Chinese were skilled in manufacturing machines and tools. For example, Lu Ban, an ancient Chinese carpenter, engineer, and inventor, made a flying machine bird out of bamboo and wood in the 5th century BCE based on mechanical principles. Zhuge Liang, who was hailed as wisdom incarnate, made a machine known as the "wooden ox and moving horse" to transport military supplies in the 2nd century. China fell behind the Western world during the modern industrial revolution and was plunged into about a hundred years of invasions by foreign powers. The Chinese then decided to catch up with the developed world in terms of science and technology. Since beginning to develop modern robots in 1972, China's robotics industry has gone through three stages: the beginnings in the 1970s, an exploration stage in the 1980s, and transformation from the 1990s onward. China gradually caught up with the developed countries based on independent research complemented by technology transfer and cooperative development. The application of robots in the Chinese manufacturing industry has become more and more widespread since China became a global manufacturing superpower at the start of the 21st century.

China has created a huge market for the robotics industry. Some 37,200 industrial robots were sold in China in 2013[3], which accounts for about one-fifth of global sales, making the country the world's largest robot consumer market. In 2014, sales reached 57,000 units, an increase of 56% over previous years, accounting for one-quarter of global sales. Likewise, robot density increased to 36, although it was only 11 just five years ago. The sales of independent brand robots climbed to 17,000 units, an increase of 78% over levels of the previous year. The annual growth rate of sales in China was 40% between 2010 and 2014, much higher than the global average.

Robots are widely used in intelligent manufacturing in China. Owing to the goal of becoming a global manufacturing power in 2025, as set out in the *Made in China 2025* plan, which was promulgated by the Chinese government in May 2015, there has been strong demand for intelligent technology since 2015. Applications of industrial robotics were being widely used in 88 industry categories within 35 industries in the domestic Chinese economy in 2015, while the previous year they had been used in just 21 industrial categories in six industries. These new areas include agricultural food processing, wine, the beverage and refined tea industry, the pharmaceutical industry, the food industry, nonferrous metal smelting and rolling, food manufacturing, nonmetallic mineral products, raw chemical materials and chemical product manufacturing, equipment manufacturing, electrical machinery and equipment manufacturing, the metal industry, automobile manufacturing, and the rubber and plastic industry.

The localization rate of China's robots is on the rise. According to statistics from CRIA, of the total 68,459 units of industrial robots sold on the Chinese market in 2015, 22,257 were sales of domestic robots, representing a growth rate of 31.3%, significantly higher than that of sales of foreign robot brands. China's domestic robotics technology developed rapidly, going from the first generation of industrial robots that were only able to perform simple work to the second generation of intelligent robots in recent years, a shift that has been supported by preferential development policies. Meanwhile, many leading international robot companies have invested in factories to respond to the enormous opportunities in China, which further improved the level of Chinese robotics.

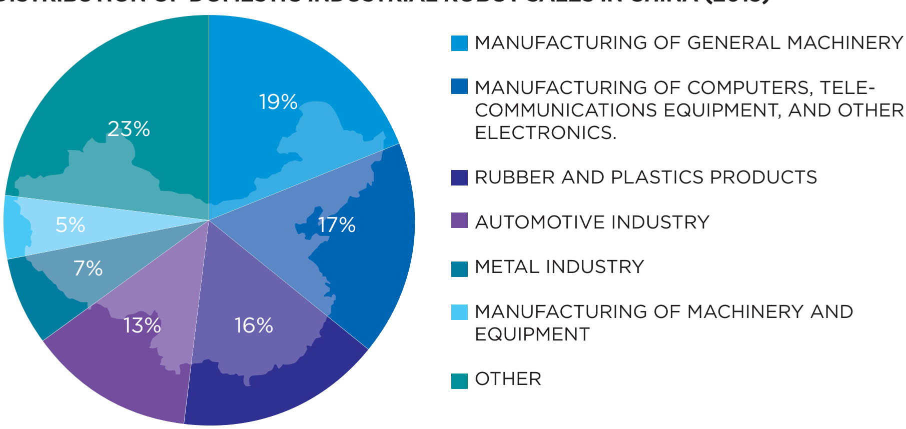
The application density of robots in China is much lower than in the other four major robot suppliers (see figure 3) and is still below the global average. Prompted by the urgent need to upgrade the country's manufacturing industry, the huge demand for intelligent manufacturing applications, and the loss of the demographic dividend, China committed to upgrading from traditional manufacturing to intelligent manufacturing, thus creating a huge potential market. According to forecasts from the IFR, China's sales of industrial robots in 2015-2017 will maintain an annual growth rate of 12%, reaching a total of 130,000 units.

78%
THE ANNUAL GROWTH OF ROBOTS MADE BY INDEPENDENT BRANDS IN CHINA

ROBOTICS AND EMPLOYMENT

The question of whether robots

FIGURE 2
DISTRIBUTION OF DOMESTIC INDUSTRIAL ROBOT SALES IN CHINA (2015)



Source: iiMedia Research (2016), Annual Research Report on China's Robotics Industry 2016.

will affect employment is a worldwide concern, especially as robots become more and more intelligent. Human beings are facing a dilemma: robots were originally invented to lighten the burden of various complex jobs and even to carry out all work and free people from labor altogether. However, these increasingly intelligent robots that could replace people's jobs are leading to concerns about robots eventually dominating the earth. Despite these worries, it seems that rather than pushing robots out of human life, humans are becoming more dependent on them.

The IFR is optimistic about the possibility of robots replacing people. In two reports on the positive impact of industrial robots on employment published in 2011 and 2013, the IFR identified robotics as a major driver for global job creation over the next five years. The impact of robots on employment was divided into the direct effect, in which the 1 million industrial robots currently in operation will create close to 3 million jobs, and the indirect effect, due to the creation of downstream activity needed to support manufacturing which can only be carried out by robots. Furthermore, the growth in robot use over the next five years will result in the creation of one million high-quality jobs around the world.

The relationship between robotics and employment in China is undoubtedly of particular concern in the major industrial powers. In these two IFR reports, China is the typical example of a market in which labor costs are rising in parallel with low-cost competition, so it is hoped that the use of robotics will maintain its competitiveness. In the IFR's view, China can maintain a stable unemployment rate while continuing to increase the number of robots it uses, which shows that robots will not crowd out employment too much. However, the IFR also notes that China faces several problems such as rising labor costs, a rapidly aging population, the transformation of the economic structure, and the need to engage in postcrisis modernization. All the same, the IFR is optimistic that China's economic activity will create more robotic applications without affecting employment levels and will be a driver for global economic recovery.

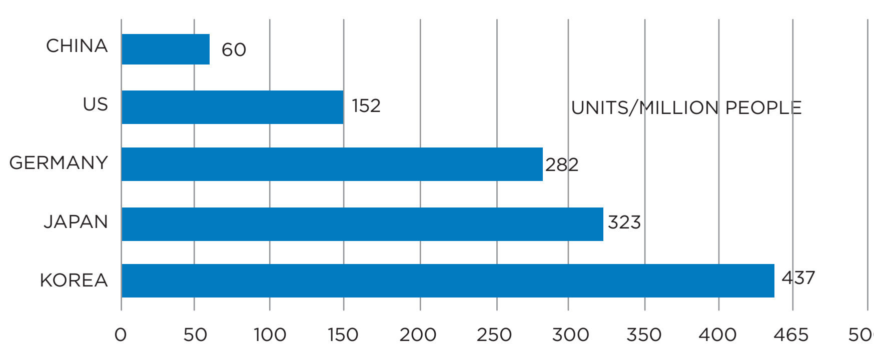
However, this analysis is not entirely persuasive. The huge scale of the Chinese labor force cannot be overlooked, nor can the extent of its economic activity, so the impact of advancing robotics cannot only be measured in terms of the stability of the urban employment rate. There are several reasons for this. First, there is no significant evidence that the urban unemployment rate is stable and that there is a correlation between this and applications of robotics. Second, although in the last five years the rate of urban unemployment remained stable at around 4.3%, an additional 16 million people have joined the labor market, so the absolute numbers of unemployed people in the sector have increased. It is unclear how far this is due to robotics. Third, the registered urban unemployment rate only reflects unemployment in cities, but China has large numbers of migrant workers who are not included in urban employment statistics. It is hard to measure whether robots will displace rural workers who are seeking employment in cities.

There are three types of relationships between robots and human workers: The first is the replacement of human workers by robots. The decision to replace a human worker with a robot depends on whether the cost of purchasing and maintaining robots is cheaper than workers' wages. When the added value of a product is not high enough to cover high wage costs, the firm will choose to buy more machines and dismiss workers. In China, those competing with robot work are mainly migrant workers and some older workers who can only perform simple manual labor due to their low skill levels. They are more likely to be crowded out of the labor market since they have no competitive advantage over robots. These industries that this applies to include manufacturing, mining, transportation, warehousing, and so on.

The second scenario is that robots will help people to perform their jobs. The demand for physical strength, high-precision operations, the ability to think, and other requirements have gradually pushed many jobs beyond the limits of human abilities in modern industry. For example, no human would be able to weld millions of plates on to a tiny chip or work for endless hours or remember and compute the same quantities of things as a machine. All the same, everyone wishes to control the ways in which robots are expanding the boundaries of human work. In China, the modernization of the manufacturing sector means that more and

35
CHINESE INDUSTRIES HAVE ALREADY STARTED USING ROBOTS IN THEIR PRODUCTION PROCESSES

FIGURE 3
APPLICATION DENSITY AMONG THE TOP FIVE GLOBAL ROBOT SUPPLIERS, 2014



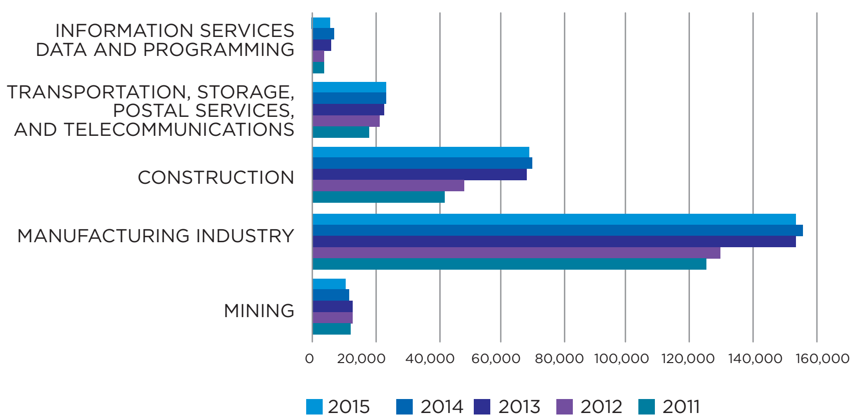
Source: iiMedia Research (2016), Annual Research Report on China's Robotics Industry 2016.

more robots are being used to assist humans in industries such as vehicle manufacturing, electronics, and telecommunications.

The third scenario is the creation of new jobs. Robots are made up of multiple components and producing them relies on a range of industries and activities. In other words, the robot industry is associated with many related industries such as metal refining, circuits, the installation and manufacturing of components, intelligent design, circuit design, and the design of data transmission. Robots may, therefore, generate many new jobs. The dizzyingly fast development of the Chinese robotics industry in recent years has led to growing numbers of both domestic and foreign robotics companies setting up operations in the country. In 2013, the size of the Chinese industrial robotics complex had reached 458 enterprises, which formed a well-defined, complete industrial chain for R&D, sales, transportation, operations, maintenance, component manufacturing, and supply, thus creating many new jobs.

In the above scenarios, only the first implies a threat of robots replacing workers, while in the second and third, employment remains stable or even increases. In the earlier stages of the robotics industry, the first scenario outweighed the other two, so robots did initially replace more jobs than they were able to maintain or create, so the effect of robotization on employment was negative, even though this effect was limited because only small numbers of robots were being used. Improvements to robotics and other related industries along the chain mean that robots can create and absorb increasingly more firms and more jobs and thus generate a positive impact on employment. This effect will be more significant in terms of the importance of the robotics in-

FIGURE 4
EMPLOYMENT IN THE MAIN ROBOTIZED INDUSTRIES IN CHINA (THOUSANDS)



Source: National Bureau of Statistics, PRC. http://www.stats.gov.cn/.

dustry within the national economy.

The impact of the Chinese robotics industry on employment is complex. Figure 4 shows employment in the main industries using robots between 2011 and 2015. As robot use increased in China after 2011, employment in these industries has also increased even though China is now one of the countries in the world with the highest numbers of robots. However, the situation changed in 2015 when employment in these industries began to fall in relation to 2014, mainly due to the fact that the annual GDP growth rate fell to below 7% (6.9%) for the first time since 2000. This downturn was also affected by industrial restructuring and modernization as humans began to be replaced by machines. However, as we stated above, this is inevitable during the early development stage of the robotics industry.

458
FIRMS MAKE UP THE CHINESE INDUSTRIAL ROBOTICS COMPLEX

THE NEW NORMAL

Most developed countries have begun to apply a re-industrialization strategy to promote the deep integration of information technologies and the manufacturing industry during this new wave of the technological revolution since the global financial crisis. The German government was the first to put forward an industry 4.0 strategy as part of its High-Tech Strategy, which aims to enhance the intelligence levels of its manufacturing sector, build a more resource-efficient industry, and integrate consumer values into manufacturing processes. In the United States, the focus is on the so-called industrial internet, which aims to revolutionize manufacturing and activate traditional industry by taking it online in order to keep US manufacturing competitive in the long term in the postfinancial crisis era. Similar modernization strategies have been launched in Japan and South Korea. The manufacturing industry is on the rise throughout the world.

As the world's number one manufacturing power, China naturally does not want to be left behind in the new industrial revolution. The country thus urgently needs to restructure and modernize its industry to breathe new life into its economic growth under the new normal. Germany's Industry 4.0 strategy has been identified as the model China wishes to follow. The Chinese government promulgated the *Made in China 2025* strategy in May 2015. This plan aims to achieve strategic manufacturing objectives in three stages: the first is to firmly establish itself as one of the world's greatest manufacturing powers by 2025; the second is to bring all the country's industries up to the average global manufacturing standard before 2035; and the third is to maintain this position at the forefront of manufacturing and build on it by 2049.

To reach these strategic objectives, the document identifies nine key areas: first, to improve the inno-

45,000
THE NUMBER OF NEW EMPLOYEES THE CHINESE ROBOTICS INDUSTRY WILL NEED IN THE COMING YEARS

vation ability of China's manufacturing industry; second, to promote the deep integration of informatization and industrialization; third, to strengthen the country's basic industrial capability; fourth, to strengthen the development of quality brands; fifth, to fully implement green manufacturing; sixth, to vigorously promote R&D in key areas, with a particular focus on next-generation information technology industries, complex machinery, tools, and robotics, aerospace equipment, naval engineering equipment and high-tech ships, advanced rail transportation equipment, energy-saving vehicles and vehicles using new energy sources, electrical equipment, agricultural equipment, new high-performance materials, biomedical and medical equipment, and ten other key areas; eighth, to actively promote the development of service-providing industries and manufacturing services; ninth, to improve the internationalization of the manufacturing industry.

To implement the Made in China 2025 strategy, which emphasizes the robotics industry as a priority development area, the Chinese government has formulated the Robotics Industry Development Plan (2016-2020) to promote the solid and sustainable development of the national robot industry. The goals of this five-year plan are to perfect the industrial robotics system and to significantly increase the country's innovation capacity and its competitiveness so as to develop top-quality robotics products, improve performance, and grow the industry sustainably.

These two strategies will undoubtedly have a positive effect on China's robotics industries and thus on employment. As we mentioned above, in the future, employment will be affected both directly and indirectly by these processes. The direct effect will be the further expansion of the scale of the industrial robotics chain within intelligent manufacturing, which will drive the development of these sectors and create more employment. The national strategies predict that the production of industrial robots by independent brands will reach 100,000 units and the annual output of industrial robots with six or more axes will pass the 50,000 unit mark. Annual revenue from service robots will exceed 30 billion yuan. Three or more internationally competitive leading enterprises will be promoted and five industrial robotics classes will be built. To meet this goal, thousands of new enterprises will emerge in the robotics industry, while a large number of sectors in the industrial chain will serve this core industry, thus creating massive numbers of new jobs. The indirect effect shows that intelligent industrialization will continually drive sustained economic growth, which will also generate more jobs. First, upgrading the robotics industry will improve manufacturing technologies and productivity, thus helping the country to move past the current downturn and guarantee the prosperity of the manufacturing sector and, with it, stable employment. Second, the prosperity of the manufacturing sector will promote the development of secondary industries and departments, which will also contribute to saving many manufacturing jobs. Finally, intelligent manufacturing will serve as the new engine for economic growth, which will enable China to maintain high growth rates and full employment.

AN INEVITABLE TRANSFORMATION

Given how science and technology develop, a future of robotics-oriented manufacturing is inevitable. A number of traditional jobs will be lost. However, at the same time, a new intelligent manufacturing model will generate many more jobs. The IFR has estimated that 300,000 people are already employed in the industrial robotics sector and an additional 45,000 people will be required by the industry within five years.

China has become the country with the highest robot sales in the world. Its robotics industry has transformed from the initial stage when robots crowded out workers to the rapid development stage following significant improvements to both the scale of the industrial chain and to intelligence levels since the introduction of the Made in China 2025 strategy and the Robotics Development Plan 2016-2020.

As part of this process, robots will inevitably come to replace humans performing simple repetitive tasks while promoting the emergence of more new industries, new business, and new jobs at the center of the industrial chain. By raising science and technology levels, they will thus create yet more jobs. In the long run, the intelligent manufacturing industry will stimulate prosperous, stable, rapid economic growth, which is the foundation for full employment. We are thus optimistic about the impact of China's robotics industry on employment in the future.

NOTES

[1] Between March 9 and 15, 2016, AlphaGo, the artificial intelligence program made by Google, beat Korean world champion Lee Sedol with a score of 4 to 1. This battle between man and machine sparked a worldwide debate about artificial intelligence and whether robots will come to replace humans. Due to the extreme complexity of Go and its profoundly cultural nature, it was thought impossible that artificial intelligence would be able to meet humans at it. But that day came unexpectedly fast.

[2] National Bureau of Statistics of the PRC http:// www.stats.gov.cn/

[3] The data on the Chinese robotics industry used in this paper was taken from China Robot Industry Alliance (CRIA). http://cria.mei.net.cn/.

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ANALYSIS

An achievable utopia

Futuristic technology and quality of life

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It is not too late to engage in the creation
of a sweeping utopia of life.

Gabriel García Márquez

INTELLIGENT ROBOTICS HAS ACHIEVED COUNTLESS ADVANCES IN THE FIELDS OF MECHANICS, INFORMATION, MATERIALS, CONTROL, AND THE MEDICAL SCIENCES. THIS STUDY CENTERS ON SERVICE ROBOTICS AND ANALYZES THE DEVELOPMENT OF TECHNOLOGIES THAT PLAY A KEY ROLE IN THEM, SUCH AS VOICE RECOGNITION, UNDERSTANDING EMOTIONS, SOFTWARE STRUCTURES, INTERACTIVE ARTIFICIAL SKIN NETWORKS, AND MICRO/NANOSYSTEMS.

Intelligent robotics has achieved countless advances in the fields of mechanics, information, materials, control, and the medical sciences. This study centers on service robotics and analyzes the development of technologies that play a key role in them, such as voice recognition, understanding emotions, software structures, interactive artificial skin networks, and micro/nanosystems.

The rapid development of new information technologies and the internet, new materials, new energies, automation, and artificial intelligence have fostered advances in the development of intelligent machines and robotics. Thanks to the benefits of new technology, there is an increasing chance that robots will help or replace humans in carrying out dangerous, physically challenging, or complicated tasks effectively and efficiently. It is even hoped that robots will come to provide support services for people's daily lives and expand the scope of their activities and abilities. For all these reasons, the robot technologies that were traditionally used in industrial manufacturing have been adapted and are making inroads into the fields of medical care, education, entertainment, exploration, surveys, biology, and disaster relief. In this paper, we describe current research and development plans for robotics around the world, analyze state-of-the-art technologies, and predict the future of service robots.

SERVICE ROBOTICS

According to the 2016 Report of the International Federation of Robotics (IFR), the number of service robots sold in 2015 increased by 25%, and sales rose by 14% to a new record of US$4.6 billion (IFR, 2016). Sales of surgical and rehabilitation robots are projected to reach US$7.2 billion dollars for 2016–2019, while those of automated guided vehicles (AGVs) used in logistics system are expected to reach US$5.3 billion. Sales of household cleaning and entertainment robots will go from 3.6 million in 2015 to about 30 million, as shown in figure 1, and the number of robots designed as assistants for the elderly and the disabled will increase to 37,500 units and a value of up to US$9.7 million dollars. From these statistics, it can be seen that the demand for service robots is going through a historic breakthrough moment.

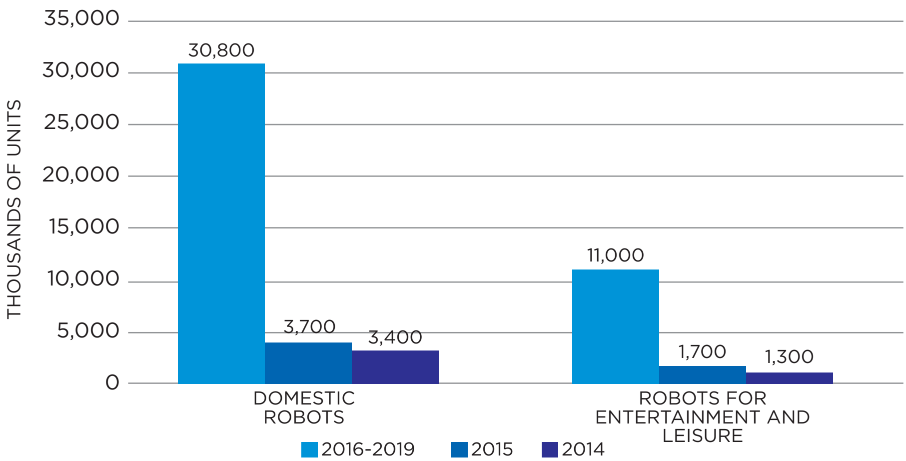
Currently, service robot R&D and manufacturing is mostly concentrated in Europe (43%) and North America (37%), with Asia accounting for merely 20%. Typical examples of service robot organizations include the Computer Science and Intelligence Laboratory at MIT, the Artificial Intelligence Laboratory at Stanford University, the Robotics Research Institute at Carnegie Mellon University, the Human–Machine Interaction Laboratory at Georgia Institute of Technology, the Robot Research Institute at Waseda University, Honda's Robot Research Institute, the Intelligent Robot Research Laboratory at the University of Tsukuba, the Robot Research Laboratory at the German Aerospace Center, the Application Research Center at Fraunhofer-Gesellschaft, the Underwater Robot Research Laboratory at the Universitat de Girona, the Shenyang Automation Research Institute at the Chinese Academy of Science, the Robot Research Institute at Beihang University, the US firms iRobot, Remotec, and Northrop Grumman, the British firm ABP, the Saab Seaeye Underwater Robot Corporation, the US Intuitive Surgical Robot Corporation, Germany's Reis Robot Group, the Swiss ABB Corporation, Japan's Yaskawa Electrics, Canada's Pesco, France's Aldebaran, and China's Xinsong Robot Corporation and Harbin Boshi Automation Corporation (Wang, Tao, and Chen, 2012).

US$ 5.3 BILLION

IN SALES OF AUTOGUIDED VEHICLES

Interestingly, more and more companies are springing up in this new market. The pursuit of breakthroughs in robotics and the development of the robotic industry has become a

FIGURE 1
ROBOTS SERVICE ROBOTS FOR PERSONAL/DOMESTIC USE
UNITS SOLD IN 2014 AND 2015 AND ESTIMATIONS FOR 2016–2019



Source: IFR World Robotics (2016).

IMAGE 1
HOUSEHOLD SECURITY MONITORING ROBOTS

global priority. There has been substantial progress in household and educational robots, rehabilitation robots, and bionic robots.

DOMESTIC AND EDUCATIONAL ROBOTS

Household and educational robots are mainly used to clean the home, monitor household security, and provide healthcare and emotional services. The most representative of this type of robot include the Roomba vacuum cleaner series manufactured by iRobot (Tao, 2015), the Mint robot (Xu, Zhang, and Du, 2009), and the Aquabot swimming pool cleaner (Xu, Yin, and Zhou, 2007). Personal assistant robots include the PR2 from Willow Garage and FURo, manufactured by FutureRobot (Ren and Sun, 2015). Moreover, Independence Technology is developing the iBOT4000 wheelchair, which can climb stairs (Guo, Xu y Wang, 2013).

The robots shown in image 1 monitor household security using visual sensors and transmit these images to the owner and can also detect when there is fire. If the robot senses that there is a fire, it will inform the fire service directly and keep the home owner informed about what is going on.

Emotional companion robots (Lu, 2013) can be used to set up video communications between relatives who live far from one another and the elderly or children. This sort of robot can also relieve tension via visual and physical means. It can download news, books, or music in keeping with the tastes of the elderly or children and then can read or play these materials.

MEDICAL REHABILITATION

Artificial intelligence is now in demand to provide healthcare managers and providers with new types of information. Wireless interconnection has altered traditional medical services as more and more uses are being found for rehabilitation robots within clinics, as part of rehabilitation programs, and in the home. Progress in the field of medical instruments and their ability to gather real-time health information in a convenient, nonintrusive manner is transforming healthcare services.

Current technologies can effectively analyze trends in health indicators, monitor disease development, provide early, customized treatment. For example, Intuitive Surgical has developed a platform that provides 3D visuals during robot-assisted surgical operations and allows surgeons to design and control each operation with multiple degrees of freedom. Image 2 shows the surgical robot developed by Intuitive Surgical (Li, G. et al., 2015). This system has already been installed and is operating in over 2000 research centers and hospitals.[1] Image 3 shows the Discovery IGS 730 surgical robot (Wen et al., 2016), developed by GE Healthcare and BA. It uses a 3D imaging system for minimally invasive surgery and is able to provide extremely high-quality images and complete freedom of movement within the workspace.

Image 4 shows some examples of robotic exoskeletons, including the US Raytheon Sarcos XOS (DDN, 2010), the Israeli (Se, Han, and Seon, 2015), the Japanese HAL3 (Yang et al., 2012), and the "Iron Man" developed by the University of Electronic Science and Technology of China (China Intelligent Manufacturing Network, 2016). These robots can get paralyzed patients out of wheelchairs and enable them to walk normally. They are also able to sense tiny movements and variations in the balance of paraplegic patients, and then help them stand up, walk, or even climb stairs.

37,500

ROBOTS WILL TAKE CARE OF THE ELDERLY BY 2019

BIONIC ROBOTS

Robotic pets have been gaining

IMAGE 2
DA VINCI SURGERY ROBOT

IMAGE 3
ROBOTS WILL TAKE CARE OF THE ELDERLY BY 2019

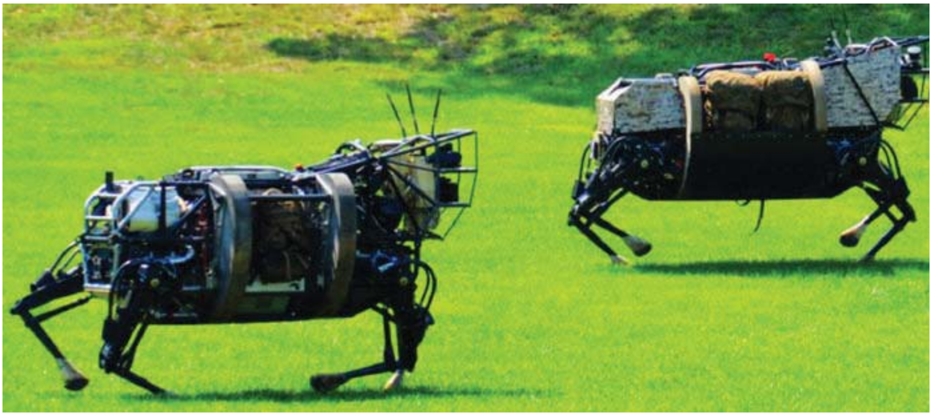
popularity in western countries and Japan. In addition to being used for entertainment, robotic animals can also carry out monitoring and transportation tasks in the military and service industries. In 2005, Boston Dynamics, founded by MIT, came up with the world's first solution to modeling, controlling, and driving a four-footed robot, and developed the first example of these, known as BigDog, as shown in image 5 (Boston Dynamics, 2016). The company then went on to design an entire series of four-footed robots. The four-footed robot developed by the China South Industries Group Corporation consists of a foot-shaped mechanical system, a power unit, a sensor system, and a controlling system (Li, M. et al., 2015). This can be used as a general platform in any type of armed combat, and for disaster relief, reconnaissance, geological exploration, and transporting goods across hostile terrains.

Swiss scientists have developed a robotic grasshopper (Wang et al., 2015), shown in image 7, which can cross uneven terrain with small obstacles and jump to a height of 60cm. Due to its flexibility and durability, it has the potential to be used to explore remote regions on earth and even on other planets. Harvard researchers have developed a robotic fly that uses flight principles that are similar to those of real flies, as is shown in image 8. This robotic fly weighs 60 milligrams and has a wingspan of 3cm. It is mostly used in reconnaissance and relief operations (Wang and Zhou, 2007).

With regard to humanoid robots, the aim of studies carried out in Japan and South Korea is to make robots a part of daily human life. Examples of these are the Japanese ASIMO humanoid robots (Hill and Herr, 2013) shown in image 9 and the guide robots from South Korea. Targeted at individuals, families, and the service industries, NAO human-shaped robots from France are mainly used for entertainment (Singh and Nandi, 2016). JiaJia, an interactive robot produced in China, can move its eyes naturally and make its mouth shape consistent with the sounds it is pronouncing (Se,

IMAGE 4
ROBOTIC EXOSKELETONS

IMAGE 5
OUTDOOR TEST OF THE FOUR-FOOTED ROBOT DEVELOPED BY BOSTON DYNAMICS



2016). It is also equipped with functions like understanding human–machine dialogues, microfacial expressions, matching mouth shapes and body actions, automatic positioning and navigation in a wide range of dynamic environments, and cloud services (image 11).

Now an integral part of some people's lives, service robots have moved from the era of information technology to that of big data. The rapid development of new materials, microelectronics and manufacturing technologies, intelligent recognition, big data, and artificial intelligence technology (AIT) has brought robots' ability to perceive and recognize things much closer to that of humans or other creatures. Consequently, we need to solve a series of problems such as recognizing and navigating through unstructured environments, self-diagnosis and repairing of faults, understanding human emotions and motion perception, identifying and extracting human semantics, memory and intelligent deduction, multimodal interactions between humans and machines, and collaborative work between multiple robots.

VOICE RECOGNITION

Service robots are intelligent devices that integrate multiple technologies which are used to provide services that people need in unstructured environments. They are mainly used for work like maintenance, repairs, transportation, cleaning, security, rescues, and guarding things. The key technologies underlying the industrialized development of service robots and the popularization and wide-

2,000
HOSPITALS AROUND THE WORLD ARE ALREADY USING SURGICAL ROBOTS

spread application of these include factors such as low-cost simultaneous location and mapping (SLAM), understanding visual images, reliable recognition of speech and emotions, safe decision mechanisms for human–machine interactions, applications of new materials for soft structures and human skin, learning technologies, and multirobot systems.

For example, as is shown in image 12, low-cost, highly reliable SLAM technology for service robots can move robots from an unknown position in an unknown environment and automatically locate them while they are in motion based on position estimates and maps, while also building incremental maps according to self-positioning systems, all of which combine to create automatic positioning and navigation systems (Chen et al., 2012).

As is shown in image 13, reliable speech and emotion recognition technology important factor in achieving natural, harmonious interactions between service robots and users, improving user experiences and enhancing robot usability (Murugappan, Nurul, and Jerritta, 2012). The critical issues in service robot research are how to get them to perceive and understand environments and human intentions naturally, to form human-like emotional features and expressions, and to interact naturally with people.

As image 14 shows, soft structure and human skin technologies for service robots utilize new synthetic materials to construct structures or skin in a way that is both safe and environmentally friendly. The aim of these developments is to simulate natural movement and tactile sensation using materials that can be shaped and sized in order to use them to repair and replace a wide range of damaged tissues (Du, 2013). Through such materials, robots can take on human-like forms and achieve "feelings" based on intelligence, including the tactile sensation of human fingertips.

IMAGE 6
CHINESE VERSION OF BIGDOG

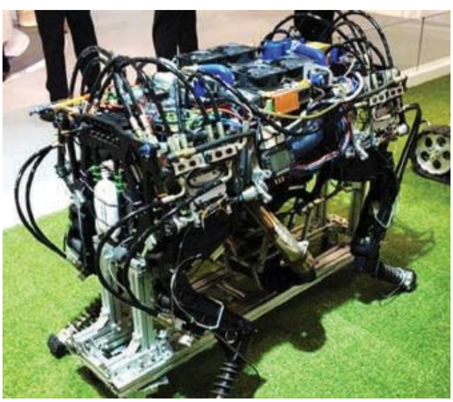


IMAGE 7
ROBOTIC GRASSHOPPER

IMAGE 8
ROBOTIC FLY

IMAGE 9
ASIMO ROBOT (JAPAN)

HUMAN–MACHINE INTEGRATION

In the intelligent society of the future, service robots for medical rehabilitation will transform health services using engineering technology to improve quality of life, provide next-generation technology, systems, and platforms for healthcare management, disease treatment, and rehabilitation. They will also provide personalized, low-cost, intelligent services to support human life. The key technologies that medical rehabilitation service robots will introduce are related to physiological data collection and micro- and nanosystems, big data mining, multimodal medical image recording, physiological function and body movement bionics, time-delayed network communication, remote security exchanges, wearables for human–machine interactions, intelligent health data, and usability assessment technology.

This section will briefly introduce medical robot technology for implants/interventions. The machine shown in image 15 reads physiological signals, electrical information from the brain, nerve conduction, feelings, and other biological information as a channel for controlling robots to help the elderly and disabled recover their abilities and use enhancement technologies (Haidegger et al., 2012). In other words, these technologies could help these people overcome the limitations they currently face by allowing people to randomly control robots according to their own needs. They thus constitute a form of human–machine integration.

Another example is big data mining in healthcare. As is shown in image 16, this technology observes and describes a series of processes and technologies that are related to health characteristics and trends within group data and can consistently monitor these over long periods of time and use them to diagnose

IMAGE 10
NAO ROBOT (FRANCE)

IMAGE 11
JIAJIA ROBOT (CHINA)

individual health conditions (Davidson, Haim, and Radin, 2015). Based on the Giant engineering system, the Internet of Things, data mining, and Traditional Chinese Medicine, this technology promotes the rapid development of a new type of observation-centered medical service technology that combines clinical medicine data science, Chinese medical science and engineering, and health management science. Big data mining in healthcare will make breakthroughs in chronic disease management and promote a shift in the focus of medical treatments from disease to health.

We will now look at wearable devices for human–machine interactions. As is shown in image 17, this technology can match individual human features and the physical and functional features of machines to

IMAGE 12
SLAM TECHNOLOGY FOR SERVICE ROBOTS

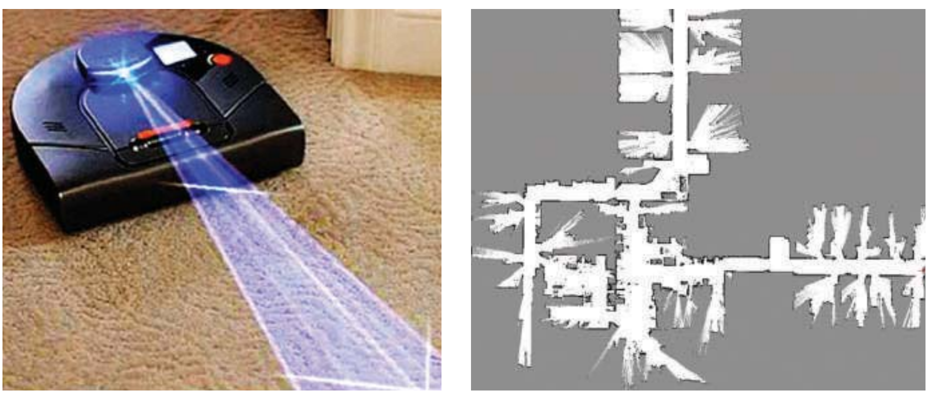


IMAGE 13
SPEECH AND EMOTION RECOGNITION TECHNOLOGY FOR SERVICE ROBOTS

establish human-centered human–machine interactions (Li et al., 2009). Human perception, recognition, behavior, physiological structure, biology, and environmental compatibility and the material, sensing, decision-making, and control features of wearable service robotics mean that they are only able to perform functions within a certain range. As a result, what defines the scope of human–machine interaction is the usability, effectiveness, and comfort of wearable service robotics. Diversified human–machine interconnection is one of the key areas where wearable robotics still needs to make progress. Given these circumstances, it will be-

IMAGE 14
SOFT STRUCTURE AND ARTIFICIAL SKIN TECHNOLOGY FOR ROBOTS

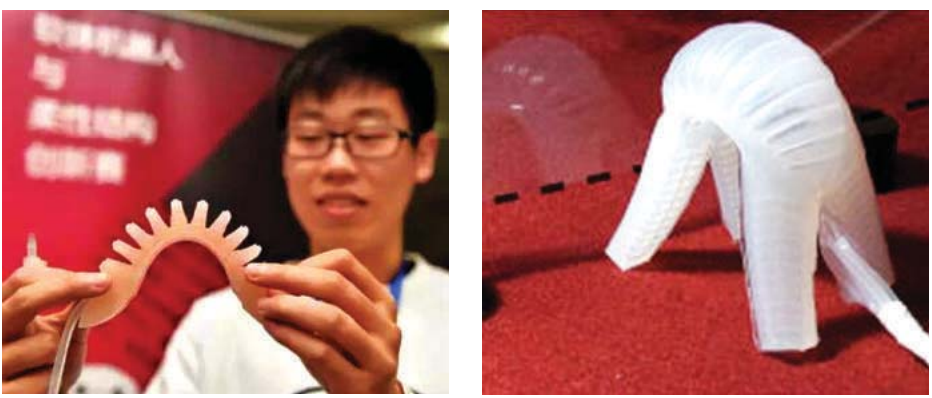


IMAGE 15
PERSONALIZED MEDICAL ROBOTICS FOR IMPLANTS AND SURGERY

come increasingly possible to achieve natural interactions between humans and machines and promote wearable robotic devices on a large scale.

FLEXIBILITY AND ADAPTABILITY

The key to reducing the size of bionic robots lies in the miniaturization of the electromechanical system, which would integrate the engine, gears, sensors, controller, and power source into a silicon chip to form a micro-electromechanical system. Making bionic robots and simulated creatures look lifelike is also a focus of research in the field of bionic robotics. In military reconnaissance and surveillance tasks, robots that look exactly like animals would be able to execute their tasks secretly and securely. The key technologies in which bionic service robotics need to make breakthroughs include mathematical modeling, control optimization, data integration, structural design, microsensors, and microcontrollers.

Bionic robots are characterized by the flexibility and adaptability of their movements, which are normally redundant or hyperredundant. Their structures are complex, and the kinematic and kinetic models they use are much more complex than those of normal robots. One of the key problems associated with them is thus the modeling and creation of controllable mechanisms. A rational mechanism design is usually the basis for the creation of bionic robots. The forms of biological organisms have evolved over millions of years. The structural features of these organisms are rational and it is almost impossible to get machines to imitate them. It will only be possible to develop highly flexible robotic mechanisms made up of simple, multidimensional joints when the body structures and kinetic characteristics of biological organisms have been studied extensively and then simplified. Such robots also need microsensors to perceive different objects and unknown environments. Problems such as the size effect, new materials, and new technologies must be taken into consideration when designing these robots.

Service robot technologies have been developing in the direction of intelligent machine technology and systems. Looking forward, robotics is integrating with mechatronic theory and technology, nanomanufacturing, and biomanufacturing to pursue cross-innovation and the development of intelligent, standardized, network-based technologies.

THE DIVERSIFICATION OF DEMAND

Having examined the research status of service robots in China and abroad and analyzed key technologies, we can now make certain predictions about how service robotics will develop into the future. For example, task-oriented AITs will be combined to develop specific robots for specific tasks. Likewise, cloud computing and internet technology will be applied to connect several robots to computer networks. The robot's knowledge will come from the cloud, which will control the robot efficiently through a working network. The robot will also learn from the cloud. As a consequence, intelligent, optimized human–machine interfaces will become increasingly simplified, diversified, intelligent, and humanized, as will the demand for this type of interaction.

Research and design will focus on the comprehension of multiple languages and natural language, the recognition of images, handwriting, and physiological information, and other types of intelligent human–machine interfaces. In this way, these technologies will respond to the demands of different users for different sorts of tasks and will improve the harmony between humans and robots. Likewise, it will be possible to coordinate, organize, and control multi-robots to complete complex tasks that cannot be performed by a single robot.

Real-time reasoning and interactive group decision-making will allow these robots to respond in complex, unknown environments and carry out tasks. Intelligent robots are able to perceive things, make decisions, and act upon them. They are flexible and can adapt to changeable environments. Artificial intelligence is an unstoppable trend and the friendly

IMAGE 16
BIG DATA MINING TECHNOLOGY FOR HEALTHCARE

IMAGE 17
MECHANISMS AND TECHNOLOGY FOR HUMAN–MACHINE INTERCONNECTION VIA WEARABLES

coexistence of humans and machines is the law that must underlie these developments in the future.

Significant advances have already been achieved in intelligent robotics, and these have made an indelible mark on industrial manufacturing, public services, and the quality of human life. However, as human demand diversifies and new technologies emerge, robots will undoubtedly play more and more roles in human life. Improving their already high levels of intelligence, establishing closer human–machine relations, and guaranteeing user security are three urgent challenges we are now facing.

Note

1 For more on this, see the specific case study on robotic surgery in this issue of *Integration & Trade*.

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CASE STUDY

ROBOTIZATION IN ZHEJIANG PROVINCE

IN PURSUIT OF DEVELOPMENT

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In May 2013, Zhejiang Province formally put forward its "555 plan": every year for the next five years, 500 billion yuan will be invested to implement 5,000 robotization projects. Over the last ten years, one way of taking advantage of the new technology revolution has been to use new technology such as big data, cloud computing, mobile internet, and the Internet of Things to escape the global financial crisis, achieve re-industrialization, and integrate the processes of informatization and industrialization.

In 2014, the government decided to launch a pilot project to this end. On September 2015, 2015, at a conference on developing the area, Qiang Li, a top Zhejiang Province leader, proposed that intelligent manufacturing should be the focus of "made in Zhejiang." Thanks to the opportunities offered by the national pilot project zone, Zhejiang Province is promoting intelligent manufacturing, using "internet + manufacturing" as the new means of production, and building up the momentum of development.

According to the action plan, Zhejiang Province will focus on four intelligent manufacturing projects: an innovation project, a promotion project, a pilot project, and a support project. It will seek to achieve four goals: promote intelligent products and equipment, foster reconstruction, develop pilot projects, and improve the support system.

Using robotization to promote intelligent manufacturing is the most ambitious of these measures. Zhejiang is carrying out 100 robotization pilot projects by assigning concrete tasks to cities and counties throughout the province and including the results in

52

THE NUMBER OF ROBOTS PER 10,000 INDUSTRIAL WORKERS IN ZHEIJANG, 44% MORE THAN THE AVERAGE FOR CHINA

government assessment schemes at all levels. It is also carrying out pilot promotion projects in key industries, has set up 22 province-level groups of experts, is organizing on-site robotization conferences, is promoting successful experiences, and boosting awareness of and enthusiasm around robotization among corporate managers (Shenglan, 2016).

In 2016, the Chinese Ministry of Agriculture formally designated Zhejiang Province as the pilot project province for agricultural robotization.[1] Robots have replaced about two million workers in Zhejiang Province since 2016.

Rising wages had been undercutting profit, which was already low for manufacturing enterprises. According to a survey on robotization conducted by Zhejiang Province Economic and Informatization Committee among 567 enterprises in 30 industries in 2013, 75.7% of enterprises listed “high labor costs” as the primary motivation for their decision to pursue robotization. According to statistics, in the past few years, labor costs in the manufacturing section in Zhejiang Province have risen sharply and already reached US$ 10,000 per worker. From 2005 to 2013, annual wages for workers at large industrial corporations in Zhejiang Province grew by 15.8% per year, one of the highest growth rates in China. If this trend had continued, the labor cost of a worker would have reached 74,391 yuan in 2016. Without automation, the manufacturing sector would certainly have moved out of Zhejiang Province.

First, robotization helps to replace low-skilled labor. In 2014, more than 1,500 enterprises in the city of Jiaxing cut 120,000 jobs through robotization.[2]The Zhejiang Jiaxi Pera Compressor Company, the pilot project enterprise, has used robotization on its newest production line for refrigerator compressors, reducing the number of workers at the production line by over 50%, from 580 to 280.[3] Zhejiang Province reduced jobs by 0.7 million in 2013 and by 0.67 million in 2014. In 2015, it reduced low-skilled jobs by 0.57 million, that is, 7.5%.[4] Zhejiang’s Yonggao Company uses 187 fully automatic injection molding machines, which are monitored by just five workers. In the past, every injection molding machine needed to be operated by at least one worker. These machines needed more than 500 workers, working in three shifts. Following robotization, the company has reduced its work force by 75% and its labor costs by 25 million yuan. In 2015, it achieved 800 million yuan worth of output using just 80 workers.[5]

Second, through robotization, companies are boosting productivity and product quality and thus solving prob-

75%

THE SHARE OF JOBS THAT HAVE BEEN CUT FROM DIFFERENT ROBOTIZED COMPANIES IN CHINA

lems related to labor shortages and employee turnover, which increases the stability of the workforce. In the past, Zhejiang Jiaxi Pera Compressor Company needed six workers to work together to operate one of its six machines. Thanks to robotization, each machine now needs only two workers and productivity has risen by 50%.[6]

Third, robotization promotes industrial transformation and modernization, boosts productivity, and raises employees' wages. From 2000 to 2010, enterprises in Zhejiang Province often faced labor shortages and the average wage of employees rose from 9,853 to 29,515 yuan, a 11.6% annual increase. In 2012, the average wage rose to 40,270 yuan, which represented an 16.8% annual increase from 2010 to 2012, 5.2% than from 2000 to 2010 (Bin, 2013).

Fourthly, robotization helps some enterprises to cope with labor shortage. According to the 2016 Survey Report of Production Line Labor Management from the China International Intellectech Corporation Human Capital Survey and Data Service Center, labor shortages have been affecting the Yangtze River delta and Pearl River delta manufacturing clusters since 2009.[7] Difficulties with recruitment and land use, high levels of energy consumption, and low output per land unit have always been the bottleneck for traditional industries in the city of Ruian, Zhejiang Province.

Fifth, there are serious conflicts within the employment structure. Industrial transformation, modernization, and robotization have saved a lot of labor and reduced the dependence of Zhejiang Province's economy on low-skilled migrant workers.

Sixth, structural unemployment has become serious. The unemployment rate in Zhejiang Province had been a stable 3%. Since 2013, it has risen sharply. In addition to the economic downturn, the main reason is the impact of corporate transformation, modernization, and robotization. In summary, from a long-term view, robotization has brought Zhejiang and China more advantages than disadvantages.[8]

In 2016, the Chinese Ministry of Finance and the Ministry of Industry and Informatization's Reform and Development Commission jointly promulgated the Robotics Industry Development Plan (2016–2020), which sets out the goals for the Chinese robot industry over the next five years, including breakthroughs in key components and premium products and a great increase in the quality, market share, and competitiveness of leading corporations.

In Zhejiang, robotization mainly takes the form of the automation of some procedures, the automation and reconstruction entire production lines, automated production lines plus industrial robots, and online equipment. The industrial Internet of Things is where the future transformation and modernization of Zhejiang is heading (Jiani, 2016). Zhejiang has developed a series of industrial parks, including Xiaoshan Robotic Industry Park, Lishui Intelligent Manufacturing Park, Dajiangdong Robotic Industry Park, and small cities with intelligent manufacturing operations.

The plan is for 36,000 large enterprises in Zhejiang Province to complete the robotization process by the end of 2017 and invest no less than 300 billion yuan each year in doing so. According to statistics, in 2015, Zhejiang Province had more than 30,000 robots in operation, accounting for 15% of the national total, more than any other Chinese province.

According to a survey by Zhejiang Province Reform and Development Commission, now there are 52 robots per 10,000 people in the manufacturing sector in Zhejiang, higher than the national average level of 36, but lower than the 66 robots per 10,000 people worldwide, and much less than the 200 robots per 10,000 people in advanced industrial nations.

The robotics industry in the province is also facing numerous problems: in needs to scale up key technologies, there is a shortage of qualified technicians, the industry is highly scattered, and the quality-price ratio is low. Despite these obstacles, Zhejiang Province is enthusiastic about developing the industry. Enterprises currently operating in the sector have shown that there are three main stages to developing this industry: vertical integration, from equipment manufacturing to integrated applications and the manufacturing of robots and key components; marketization, from R&D to commercialization; and expanding development from industrial robots to service robots (Zhejiang Province Reform and Development Commission, 2016).

NOTES

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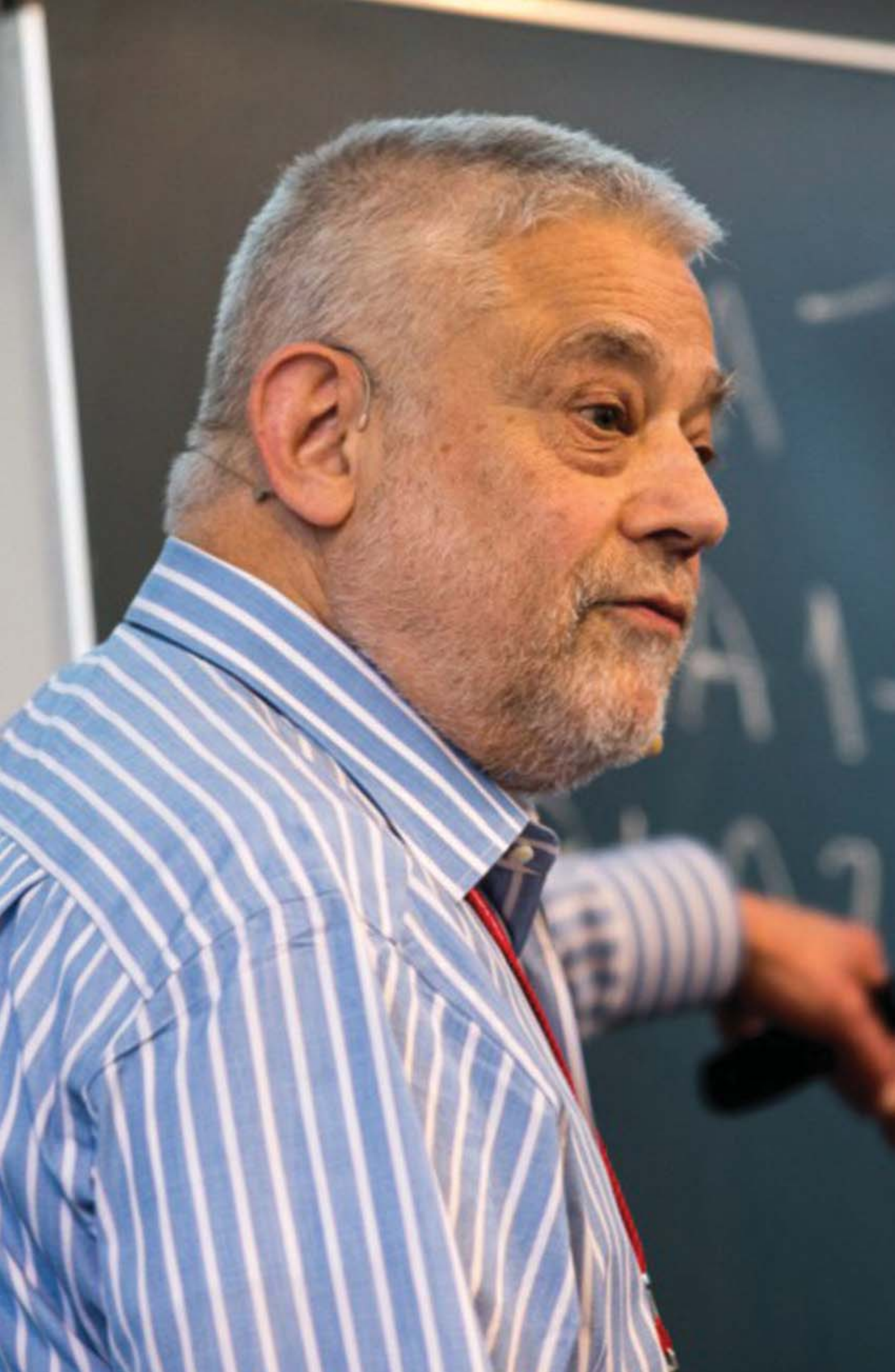


INTERVIEW

"We **need** to **teach young people** to **think** for themselves"

Manuel Blum

Turing Award Winner and Professor at Carnegie Mellon University

The Turing Award is seen as the Nobel Prize in computer science. It has only ever been given to one Latin American, the Venezuelan Manuel Blum, in 1995, for his contribution to computational complexity theory and cryptography. In this interview, Blum highlights the role of technologies in the learning process and the need to incentivize problem-solving skills among young people. He also predicts that many jobs will disappear in the future, including his own as a mathematics professor.

What are the main challenges of teaching to new generations?

There is one problem that I continually come up against: on the one hand, it's very important for students to learn to use search engines (such as Google and Baidu) to find information (and, while they're using them, to learn to distinguish reliable information from that which isn't). I encourage them to use search engines. But on the other hand, they also need to learn to think for themselves. So, in some tasks, I ask them to solve problems themselves.

If they receive outside help, is that cheating?

I tell my students that although I sometimes them to solve problems without outside help, I will never take away points for using other sources (like the web, their friends, books, their own heads) as long as they cite them appropriately. I tell them that's what good scholarship is all about. The only thing that I see as cheating is when they don't cite their sources. If they themselves are the source (the ideas come from inside their own heads), then they should give themselves credit. I remember setting a difficult homework problem. The students who solved it all pointed to the same student as being the source of their answers. What is interesting is that although the student they indicated had reached the correct answer, there were mistakes in everyone else's. The students had somehow recognized that it was the right answer, but they hadn't understood all the subtleties that it entailed.

> "MY FATHER WAS A WATCHMAKER AND HE MADE GEARS BY HAND. NO JOB IS SACRED"

Do you think that technology can be a facilitator for improving education?

Absolutely. Technology can be a huge help to education. You can use Duolingo to learn languages, WolframAlpha to solve mathematical problems, spreadsheets to store and analyze data... and so on. Computers are used everywhere today. But they need to be used even more, in every field imaginable. Biologists, chemists, astronomers, and engineers all need to be computer-literate.

What emerging disciplines are going to see radical changes.

Machine learning and robotics is

BORN IN CARACAS, VENEZUELA, MANUEL BLUM IS A PROFESSOR OF COMPUTER SCIENCE AT CARNEGIE MELLON UNIVERSITY. HE RECEIVED HIS PHD IN MATHEMATICS FROM MIT, WHERE HE WAS SUPERVISED BY MARVIN MINSKY. HE USED TO TEACH AT MIT AND IS A MEMBER OF THE UNITED STATES NATIONAL ACADEMY OF SCIENCES, AMONG OTHER ORGANIZATIONS. HE ALSO WRITES POETRY.

HIS MAJOR PUBLICATIONS INCLUDE:

"A MACHINE-INDEPENDENT THEORY OF THE COMPLEXITY OF RECURSIVE FUNCTIONS." *JOURNAL OF THE ACM.* 14 (2): 322-336. 1967.

"TIME BOUNDS FOR SELECTION." *JOURNAL OF COMPUTER AND SYSTEM SCIENCES.* 7 (4): 448-461. 1973.

"TOWARD A MATHEMATICAL THEORY OF INDUCTIVE INFERENCE." *INFORMATION AND CONTROL*. 28 (2): 125-155. 1975.

"HOW TO GENERATE CRYPTOGRAPHICALLY STRONG SEQUENCES OF PSEUDORANDOM BITS." *SIAM JOURNAL ON COMPUTING* 13 (4): 850-864. 1984.

"A SIMPLE UNPREDICTABLE PSEUDO-RANDOM NUMBER GENERATOR." *SIAM JOURNAL ON COMPUTING*. 15 (2): 364-383. WITH L. BLUM AND M. SHUB. 1986.

"CAPTCHA: USING HARD AI PROBLEMS FOR SECURITY." PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON THE THEORY AND APPLICATIONS OF CRYPTOGRAPHIC TECHNIQUES. WITH L. VON AHN, N. HOPPER, AND J. LANGFORD. 2003.

where the action is. There are many game-changing areas, such as translation, the interface between humans and machines, and much more. But in 2017, machine learning and robotics are particularly important.

Do you think that robots are threatening jobs?

Workers are already at risk. It's nothing new. My father was a watchmaker. To prove he had mastered the trade, he had to design a watch and then build it, including the gears, from scratch. He could do that. What he was never able to do was accept the fact that today, when your watch breaks, you throw it away and buy a new one. I'm a professor of computer science and mathematics. I'm very well educated. But to be honest, if we mathematicians and computer scientists do our teaching and research jobs right, my current job will disappear. No job is sacred. Some people think that computers will never be able to solve and prove difficult, interesting theorems. I totally disagree. It's only a matter of time before my job is outsourced to a computer.

What abilities and skills will technology demand?

The ability to write clearly, to think clearly, to think in mathematical terms, and, of course, to code. Students need to be able to code in languages like Python, C, C++, and Java. They need to know how to choose the most suitable programming language for each problem, know what it is that they need, when they need it, and be flexible enough to learn new languages.

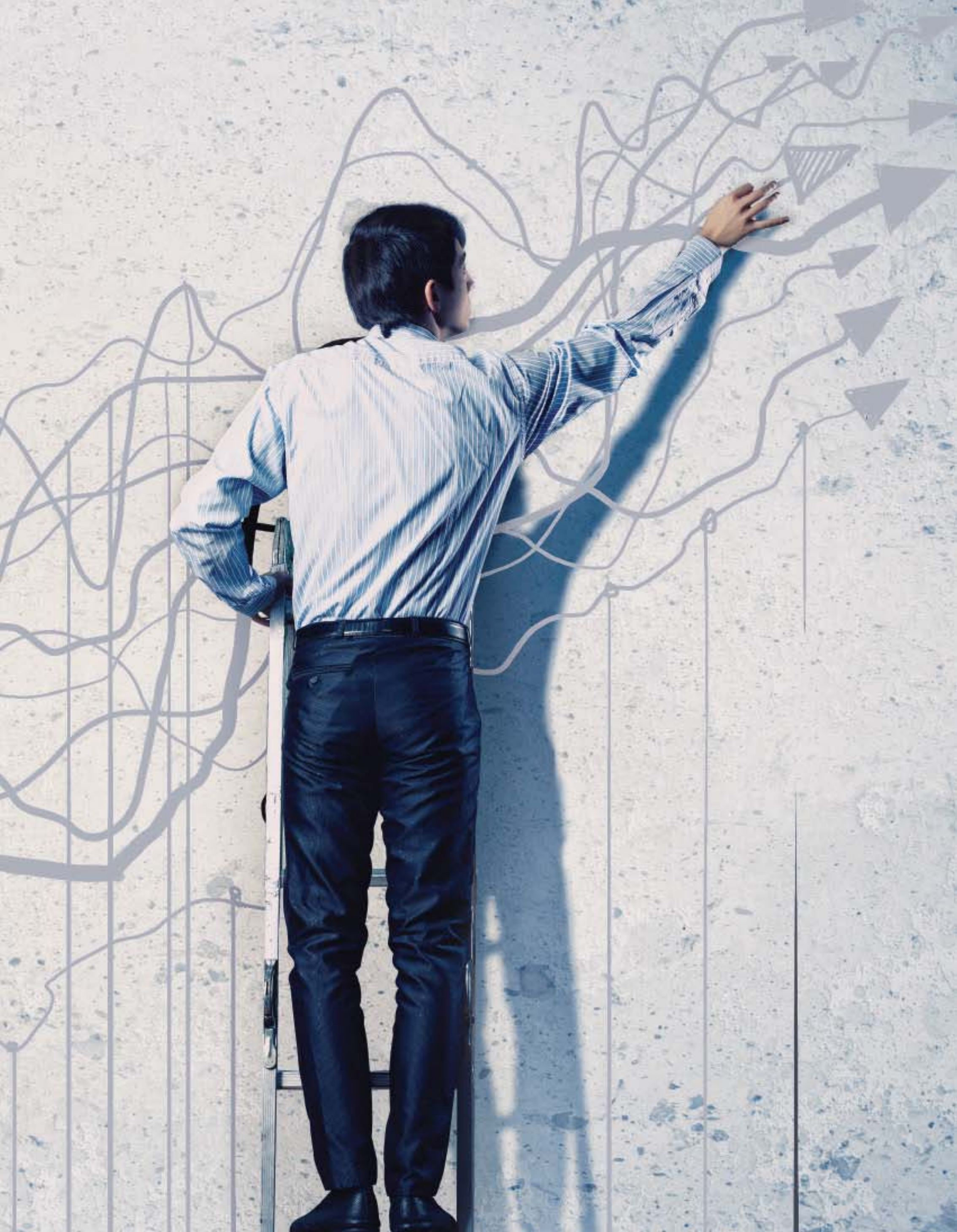
Which economic sectors have benefited the most from automation?

I would ask which sectors haven't benefited from it. There are so many that have that it would be impossible to list them all. If a sector has not yet benefited from it, then there is enormous room for improvement, like when a young person finds a new way to use computers.

A satellite account for measuring the new economy

> If knowledge can create problems, it is not through ignorance that we can solve them.
>
> Isaac Asimov

Ariel Coremberg
Beatriz Nofal
University of Buenos Aires and
Argentina's Ministry of Foreign Affairs



When analyzing the possible effects that innovation may have on employment, a country's role in trade, and global value chains, the creation of a methodological framework that has been empirically verified is fundamental. In this article, we will use the rigorous framework that forms part of the UN System of National Accounts (SNA) to compare sectors and time periods in a way that is consistent with a GDP-based methodology.

To determine the impact of innovation on the economy, we need to distinguish "what should be measured" from "how it should be measured," as Hulten (2004) argued. We also need to avoid what Nobel laureate Tjalling Koopmans called "measurement without theory" in 1970.[1]

Innovation is often described as a basic input activity or in terms of the outcomes that it generates. Investment in research and development (R&D) into products or processes is the most common measure on the input side, while patent numbers are the most common measure on the output side. However, this perspective can only be used to identify expenses or investments that are directly related to innovation and does not allow researchers to discern the sources, transmission, adaptation, and dissemination of these results at the micro-, meso-, and macroeconomic levels.

Nor does the traditional classification of innovations into final products, inputs, and processes explain the impact that innovation can have on the production sector or on welfare. For the innovations that have been acquired or generated to have the desired effect on productivity, firms need to reorganize their production processes, which prompts the need to identify organizational innovations. Likewise, reorganizing the production process would imply a series of complementary expenses and investments for these innovations to take effect, as Brynjolfsson and MacAfee (2011) have analyzed. Finally, bearing in mind the way that international trade currently operates, innovations will have different impacts depending on how the firm or sector in question is integrated into global value chains.

If we accept that the aim of innovation is to increase the knowledge in a society, we need to define the value of that knowledge in economic terms and, more specifically, how its use generates more production, greater productivity, and, ultimately, more knowledge. This poses the challenge of identifying and measuring the knowledge used and generated in the production process—that is, knowledge capital.

A review of the literature points to a set of methodologies that attempt to measure innovation activities and the results of this: compound indicators, indicators of technological intensity, prospective methodologies, satellite accounts, and knowledge accounting.[2]

COMPOUND INDICATORS

The Global Innovation Index (GII)

is a more detailed set of simple indicators for other phenomena that affect innovation performance at the national level. It is published by Cornell University, INSEAD, the World Intellectual Property Organization (WIPO) and a core research team in association with the private sector, representatives from the Confederation of Indian Industry, and the firms A.T. Kearney and du Emirates Integration Telecommunications Co.

The GII is a set of indicators that evaluate the performance of different national innovation systems and allows these to be compared. Each country's GII is made up of over 80 indicators, which are grouped into different input pillars that represent different aspects of innovation. Two of these capture evidence of innovation outputs: creative outputs and knowledge and technology outputs. Five describe input factors: institutions, business sophistication, market sophistication, infrastructure, and human capital and research. Each of these pillars is calculated as the weighted average of individual indicators. For example, the market sophistication pillar includes diverse quantitative and qualitative indicators which range from the share of private-sector credit in GDP to the ease of protecting minority investors using distance to frontier scores based on qualitative indicators of governance.

Figure 1 presents the distance between Latin America and the Caribbean and the developed world for different dimensions.

There are significant gaps between Latin America and the developed world in all dimensions. The distance to frontier is especially noticeable at the core of the innovation system for both the generation of innovation and knowledge outputs (patents, ISO 9001 certification, scientific publications, etc.) and input indicators (investment, R&D expenditure, etc.). This gap is somewhat narrower for creative outputs, which is mainly due to the region's notable cultural products. The indicators for Brazil, Chile, Mexico, and Uruguay are all above the regional average. Argentina is a striking example as the features of its national innovation system are typically "Latin American," except for infrastructure and, most notably, human capital and R&D.[3]

10%

OF GDP IS MADE UP OF INTANGIBLE ASSETS

However, like any compound indicator, the GII weights components equally without a methodological criterion and thus does not allow each indicator's contribution to employment, growth, or productivity to be calculated, or to be compared with macroeconomic and sector-specific aggregates. For example, the GII does not allow one to determine how far each innovation input (such as education and skills, R&D, and the use of ICTs) contributes to generating macroeconomic and mesosectoral productivity. Although the GII includes patent numbers as an example of innovation results, patents are not the only innovation output and they cannot be compared with productivity metrics.

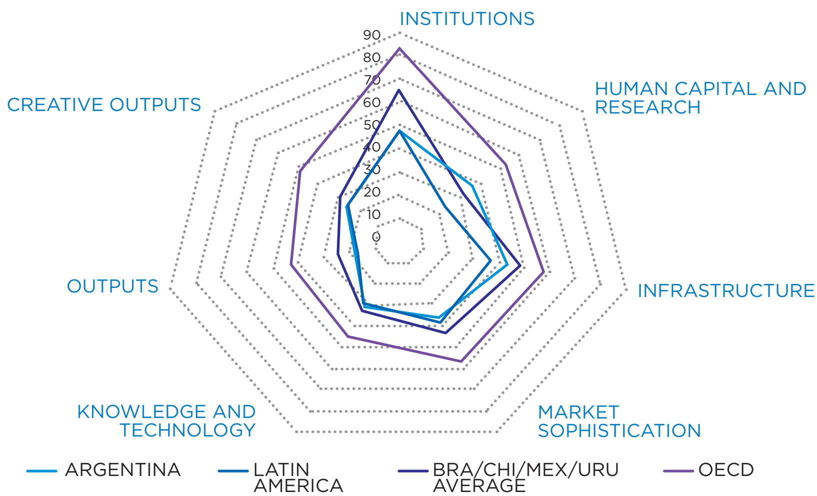
TECHNOLOGICAL INTENSITY INDICATORS

The traditional approaches put forward by the OECD (2013a) and Eurostat (2013) disaggregate production activities according to their technological intensity via the share of R&D expenditure over production value, or value added, or employment of highly skilled labor.

The OECD set out to classify trade flows between countries to determine the relationship between growth, globalization, and innovation. To do so, it created a classification of industrial activities according to their degree of technological intensity, dividing the different manufacturing sectors into high, medium-high, medium-low, and low technological intensity. Technological intensity is defined in relative terms according to the R&D efforts undertaken in each sector or branch of manufacturing.[4] The ranges used to differentiate the technological intensity of industries were as follows: branches that invest more than 5.5% of their turnover in R&D activities are considered high-technology; 5.5%–1.5%, medium-high; 1.5%–0.5%, medium-low; and those that invest less than 0.5% are seen as industries with low technological intensity.

However, the OECD subsequently instigated the design and standardization of the measurement of R&D and innovation activities internationally. The earliest measurements of innovation inputs are in the Frascati Manual, which was followed by the Oslo Manual and the Bogotá Manual, which allow innovation to be approached as a complex process that generates changes in the organization of production, networking, the adaptation of innovations, and new products and processes.

FIGURE 1
GLOBAL INNOVATION INDEX (GII) BY REGION AND AGGREGATE DIMENSIONS



Source: Compiled by the authors.

INNOVATION SATELLITE ACCOUNT

The SNA approach allows theories and methodologies to be adapted to a phenomenon such as innovation, which needs to be defined and measured in a way that encompasses products and activities that are not necessarily compatible with traditional GDP classifications. This issue takes the form of so-called satellite accounts (SAs). To measure the potential impact of innovation on a country's economy, researchers tend to simulate what are known as "indirect and induced effects" through production linkages.

The standard classifications of products and industries (CPC and ISIC) arrange all industries and products at the same hierarchy level. The SNA is flexible enough to regroup them so that a key sector can be analyzed. By so doing, the standard supply and use tables can be estimated for the sector that one wishes to measure by expanding on details that do not appear in the standard presentation. This analysis is contained in the NAs: activities and products need to be regrouped based on a query or focus that usually touches on several activities or aspects of them.

The best-known international examples are the NAs for tourism and health. Recent examples of NAs for Argentina include studies on the intellectual property industries (Massot, Prieto, and Wierny, 2013) and the business of soccer (Coremberg, Sanguinetti, and Wierny, 2016). These experiences have focused on the supply side by including production activities that are associated with, connected to, and generated by the main activity. However, they do not fully calculate the demand side, for which they would need to include not just foreign trade flows but also consumption and investment.

50%

OF GROSS FIXED CAPITAL FORMATION IN EUROPE IS FOR GOODS THAT ARE ONLY MEASURED PARTIALLY

Few NAs have been developed for knowledge, although significant work has been carried out by official NA bodies such as the CBS in the Netherlands and the Bureau of Economic Analysis (BEA) in the United States. In line with the 2008 SNA recommendations, the BEA has counted R&D and expenditures on intangible intellectual property assets as investments since 2013. These include the creation of entertainment, literary, or artistic originals and other intangible assets that have already been capitalized, such as software, adjusting estimates of GDP, savings, investment, and foreign direct investment. The OECD has also created work groups to measure so-called knowledge-based capital (KBC), but it does so partially, only taking intangible assets and the capital of employees in certain jobs into account.

An exhaustive estimate of the knowledge NA would allow researchers to identify and quantify knowledge-generating production activities, but it would not quantify the impact of knowledge on productivity, employment, and trade in production activities that demand, acquire, and adapt innovation and knowledge but do not generate these. Similarly, although the 2008 NSA and the BEA have capitalized R&D and the creation of intellectual property assets, they continue to omit a series of intangible assets that have a major impact on firms' productivity, profitability, and competitiveness.

KNOWLEDGE CAPITAL

Productivity has been stagnating in Latin America and did so even during the period of growth that came with the commodities boom. Despite the effort that many production sectors have made, the macroeconomic gap between the region and developed countries for a range of partial indicators for the intensity of investment in technology continues, despite a substantial improvement in labor skill. However, productivity performances have varied within the region. Using the methodologies analyzed thus far, it is not clear which differential variable at the mesosectoral level will enable R&D to lead to major productivity gains and thus greater competitiveness in international trade.

This is the conclusion reached by authors such as Brynjolfsson and McAfee (2011), who point out that one of the most important factors for innovation to generate increased productivity and profitability in firms is for it to be accompanied by a reorganization of the production process and investment in intangible assets and human capital. The most productive firms reorganize their production processes, incentive systems, information flows, and other aspects of organizational capital to take maximum advantage of technology. This, in turn, requires a more skilled workforce. According to these authors, each dollar invested in hardware requires another ten to be invested in complementary organizational capital. For the organization to be successful, high levels of investment in intangible assets are needed, which organizational capital is part of. Intangible assets are generally much harder to generate and change, but they are also more important to the organization's success.

The 2008 SNA and the *Measuring Capital OECD Manual* (2009) include traditional capital assets within the asset boundary: tangible capital goods (machinery, constructions, livestock for breeding, etc.) and some intangible assets (software, goodwill, patents, etc.) and natural resources (subsoil assets, agricultural land) that are subject to property rights. Changes to the latest version of the SNA include the recommendation to explicitly measure capital services in line with recent advances in measuring productivity and the sources of growth: World KLEMS is the standard initiative used to measure and compare

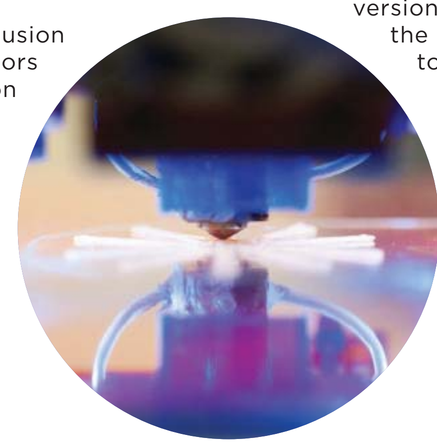


TABLE 1
KNOWLEDGE CAPITAL

TANGIBLE ASSETS	ICTS	HARDWARE
		TELECOMUNICATIONS
INTANGIBLE ASSETS	ICTS	SOFTWARE
		DATABASES
		MINERAL AND PETROLEUM EXPORATION
	PROPERTY OF INNOVATION	SCIENTIFIC R&D
		ARTISTIC AND ENTERTAINMENT ORIGINALS
		NEW PRODUCTS/SYSTEMS IN FINANCIAL SERVICES
		DESIGN AND OTHER NEW PRODUCTS/ SYSTEMS
	ECONOMIC COMPETENCIES	BRAND VALUE
		ADVERTISING
		MARKETING
		FIRM RESOURCES
		STAFF TRAINING
		HIRED HUMAN CAPITAL
		ORGANIZATIONAL STRUCTURE

Source: Coremberg (2016), Corrado et al. (2005) and Mas and Quesada (2015).

productivity internationally and ARKLEMS+LAND is the Argentine version of this.

As Mas and Quesada (2015) mention, for investment in ICTs and R&D to have a positive effect on firms' productivity, profitability, and market value, a series of complementary investments need to be made to facilitate the efficient adaptation of the remaining components of the production system: education and worker training, brand creation and building, customer loyalty, and other expenses outlaid within the company or subcontracted on the market.

Jorgenson (2001) defines investment as "the use of current resources in the expectation of the investor achieving greater future return." A broader definition would be any use of resources that reduces current consumption in order to increase it in the future (Corrado, Hulten, and Sichel, 2005). It therefore follows that investment in both the generation and use of knowledge needs to be included alongside investment in infrastructure, machinery, and equipment.

In this way, a series of outlays on intangible assets are included within the asset boundary for knowledge capital (see table 1).

Note that this definition expands the asset boundary beyond that used in the 2008 SNA: several factors that the SNA handles as running costs that form part of intermediate consumption are capitalized as production factors here, namely expenditure on design and systems, advertising, market research, expenditure on redesign of organizational structure, and training human capital.

The inclusion of private-sector expenditure on intangible assets in the investment category has significant effects on both the aggregate value of the economy and macroeconomic investment. Mas and Quesada (2015) found that the inclusion of intangible assets increases developed countries' GDP by approximately 10%, doubles investment levels in the United

States, and represents almost 50% of traditional net capital formation in the European Union.

Likewise, building on these proposals from Corrado et al. (2005) and Mas and Quesada (2015), we have included human capital stock in knowledge capital in the form of firms' investment in staff training and hired human capital, as firms demand and use skilled labor trained by other firms; through expenditure on staff training; the experience that workers have accumulated previously in the labor market; and the training they accrue through the education system.

What we are proposing here is for knowledge capital to include expenditure on both the tangible and intangible assets used to generate knowledge and innovation, along with assets that incorporate accumulated knowledge into production according to the classification set out in table 2.

Real-estate assets and unskilled labor are excluded, as they do not include or generate new knowledge. Consequently, we describe them here as "nonreproductive capital" in a way that is analogous to the exclusion of housing as capital, in that nonrental housing is not associated with production activity carried out by certain economic agents.

In this way, by including assets that generate knowledge and the organizational capital needed for knowledge to be used effectively within the production process, we are not only expanding the accounting method for a given country's wealth but also identifying the production services that uses of these assets generate, which enables us to quantify the impact of knowledge capital on growth.

EXTENDED ACCOUNTING

The methodology that we are putting forward identifies knowledge capital by defining assets that sustain and support growth and welfare. Consequently, building on the approach of Pérez and Benages (2015), we are including intangible assets in the knowledge capital.

To do so, we need to define sector-specific indicators for knowledge intensity and identify how these contribute to economic growth. In keeping with Pérez and Benages (2015), we define sector-specific indicators for knowledge intensity as the value of knowledge services used in relation to their production value. We do not classify sectors a priori into categories that are more or less knowledge-intensive, which prevents the discontinuity caused by thresholds that arbitrarily separate groups from one another while enabling us to analyze innovation dynamically. This is expressed as follows:

(1)

$$p_j V_j = \sum_{i=1}^{m} r_{i,j} K_{i,j} + \sum_{h=1}^{n} w_{i,j} L_{i,j}$$

where *pV* is the value added of sector *j*, r_i, is the cost of the use of class *i* capital used by sector *j*, and *w* is the unit wage paid for class *h* work in sector *j*. Grouping production factors by the level of knowledge incorporated *k* allows us to define the knowledge intensity of the value added for sector *j* as:

$$I^k = \frac{K_j^k}{p_j^X V_j}, \text{ con}$$

$$K_j^k = \sum_{i=1}^{m} r_{i,j}{}^k K_{i,j}{}^k + \sum_{h=1}^{n} w_{i,j}{}^k L_{i,j}{}^k$$

TABLE 2
EXPANDED KNOWLEDGE CAPITAL

EXPANDED KNOWLEDGE CAPITAL	**TANGIBLE ASSETS**	**NON-ICTS**	MACHINERY AND EQUIPMENT
			INFRASTRUCTURE
		ICTS	HARDWARE
			TELECOMMUNICATIONS
	INTANGIBLE ASSETS	**ICTS**	SOFTWARE
			DATABASE
		PROPERTY OF INNOVATION	MINERAL AND PETROLEUM EXPLORATION
			SCIENTIFIC R&D
			ARTISTIC AND ENTERTAINMENT ORIGINALS
			NEW PRODUCTS/SYSTEMS IN FINANCIAL SERVICES
			DESIGN AND OTHER NEW PRODUCTS/ SYSTEMS
		ECONOMIC COMPETENCIES	BRAND VALUE
			ADVERTISING
			MARKETING
			FIRM RESOURCES
			STAFF TRAINING
			HIRED HUMAN CAPITAL
			ORGANIZATIONAL STRUCTURE
NON REPRODUCTIVE CAPITAL	REAL ESTATE		
	UNSKILLED LABOR (PRIMARY EDUCATION OR LESS)		

Source: Compiled by the authors.

The sum of all sector-specific aggregate values gives the macroeconomic GDP.

The impact of knowledge capital on growth and productivity can be measured using the growth accounting approach. Macroeconomic growth accounting to identify the main sources of a country's economic growth yields the following equation:

(2)

$$\hat{V} = \varepsilon_k \hat{K}_k + \varepsilon_{nk} \hat{K}_{nk} \varepsilon_L \hat{H} + \hat{A}$$

where *V* is GDP; K_k is aggregate knowledge capital services; K_{nk} is nonreproductive capital services; *H* is hours worked; *L* is human capital services; *A* is total factor productivity (TFP) or the Solow residual; and ε_i represents the product elasticity of each primary input. Likewise, the growth rate for each of the factors is a Tornqvist aggregate of all subclasses of capital and labor (Coremberg, 2009).

Capital services are estimated by reweighting capital stock by asset type according to use costs rather than by asset prices, as per the standard methodology used in, for example, OECD (2009) and Coremberg (2009). If factor elasticities (e) are obtained from national accounts, the contribution of knowledge to economic growth will be given by the share of each knowledge-generating factor of production in GDP, which we can express as a, multiplied by the growth rate.

However, the economic literature has argued that greater expenditure on R&D, improving human capital, ICTs, or technical progress incorporated into machinery and equipment has an additional effect on economic growth that goes beyond its costs.

If there is any type of externality, the accumulation of knowledge capital can be induced by growth in productivity. The learning-by-doing effects that derive from the externality that aggregate investment brings about in firm productivity through increases in the stock of knowledge, as described in Arrow (1962) and Romer (1986), can be extrapolated perfectly to knowledge capital typologies. So, too, can the externalities generated by returns on investment in machinery and equipment, as described in Bradford DeLong and Summers (1991). In this case, true elasticities, ε, may be greater than 1.[5]

In ideal terms, knowledge capital contributes to economic growth through its growth rate weighted by its use cost, but also through the externalities that it generates. In the case of positive externalities, the true factor elasticities (ε) of knowledge capital outstrip its share in terms of costs (α). In this case, the factor elasticity of knowledge capital and measured TFP can be shown to yield the following:

$$\varepsilon_k = \alpha_k + \gamma_k$$

$$\hat{A}^M = \hat{A}^V + \gamma_k \hat{K}_k$$

where γ is the externality generated by knowledge capital.

This demonstrates that, given that these externalities cannot be measured directly, they are included in measured TFP. Given that TFP is a residual, it also captures phenomena other than externalities that may increase the productivity and efficiency of the economy, such as scale effects, markups, quality effects, or embodied technical change that was not captured correctly when factors were measured. However, if the externalities are macroeconomically significant, the growth in TFP can be expected to be positive and significant.

The following scheme summarizes this argument:

ΔK_k---------------------------- ΔQ

ΔK_k--------------------------- $\Delta (Q/L)$

ΔK_k--------------------------- ΔPTF si y solo si $\varepsilon_k > \alpha_k$

To verify potential externality, we would need to prove the correlation between knowledge capital and TFP econometrically. We would also need to establish the temporal precedence of innovation and knowledge generation using a causality test. However, even if these factors are verified, the coefficients may still be biased, inconsistent, and subject to endogeneity problems if knowledge capital is not specified correctly or if another component, such as natural capital, is excluded from these sources of growth (Coremberg, 2016). However, if measured TFP is low or negative, this could be symptomatic of two alternative phenomena. First, the nonexistence or macroeconomic irrelevance of the externalities of a given emblematic or special production factor, in this case, one that originates in investment in a certain type of knowledge capital. Second, the limited use of this factor by the economy.

EMPIRICAL EVIDENCE

In this section, we analyze

Latin America's growth profile by restricting the contribution of knowledge capital to ICT capital services, workforce skill, ad TFP. The inclusion of TFP is justified because part of the knowledge generated by the knowledge society is used in the production sector at no cost. In other words, it has similar nonrivalry and nonexcludability characteristics as intangible assets (see figure 2).

The main factor that explains GDP growth in Latin America is non-ICT capital, followed by labor and knowledge capital, as per the limited definition from the database used here. Using this restricted measurement, the contribution of knowledge capital varies throughout the region. A decomposition of this contribution may provide more evidence regarding the factors that explain its performance, as is shown in figure 3.

The fundamental variable that explains knowledge capital is TFP. This variable underlies the positive and negative performance of the contribution of knowledge capital in each country. ICT capital and workforce skill make a notable contribution in Costa Rica and Chile. The "quality" of the workforce is a key factor in all countries included in the sample.

However, given the limited definition and the absence of a measure of natural capital in the Total Economy Database (TED), we cannot attribute the dynamism of TFP directly to the externalities of intangible assets or ICTs, nor can we specify the scale of this.

MEASURING TRADE

Standard analyses of international trade and growth stress that trade flows allow knowledge to be adapted and spread through imports of high-tech capital goods and inputs. Likewise, exports with high value added may be responsible for spillover effects through the economy due to production chains, in addition to the scale and learning-by-doing effects that they may bring about in firms that take part in international trade. Global value chains are an inescapable fact of life and linkage effects should thus take the spread of knowledge through trade flows into account (Grossman and Helpman, 1991, 2015; Hausmann, Hwang, and Rodrik, 2007; Hausmann et al., 2011).

The methodology for knowledge accounting that we have put forward here can be applied to measuring trade flows. The disaggregation of production value into knowledge factor components can be applied to exports using the assumption of proportionality. This assumption is used by the World Input Output Tables (WIOD) project and the OECD to calculate global value chains. However, the assumption of proportionality supposes that the production functions of domestic output and exportable output are identical.

Different international trade databases allow us to calculate the technological content of exports. However, these draw on unique reference indicators that are based on allocations of fixed value-added coefficients obtained for a single geographic location and period, so our earlier critique of traditional indicators for technological sophistication also applies to them. Comparable indicators based on R&D expenditure are similarly limited, as they exclude other, even more significant components of knowledge capital, such as intangible assets, human capital, and ICTs.

Knowledge accounting for exports would yield the knowledge intensity of the set of assets used in production, provided one accepts the assumption of proportionality.

The knowledge intensity of a given area of activity may be different depending on whether gross value added or total output (sales) is taken as a measure of production. There may be firms that sell products with high knowledge content due to this having been incorporated by other firms into intermediate inputs (purchases) that the selling firm acquires, even though the latter is not knowledge-intensive due to the importance of the machinery or skilled labor that they themselves use in relation to the value added that they generate. Consequently, to be able to apply knowledge accounting to a particular branch of production, we need to be able to quantify the contribution of intermediate inputs to growth in production. With regard to international trade, we need to measure the knowledge intensity of imported and domestic intermediate inputs as well as the intensities of the remaining production factors contained in the exports, as follows:

(3)

$$p_j^X X_j = \sum_{i=1}^{m} r_{i,j} K_{i,j} + $$
$$+ \sum_{h=1}^{n} w_{i,j} L_{i,j} + \sum_{l=1}^{p} p_{j,i}^{M} M_{i,j}$$

where pX is the value of exports at current prices for sector *j*; r_i, is the use cost of the capital used by sector *j*; w_i is the unit wage paid for class *h* work in sector *j*; and pM_i is the price of class intermediate inputs used by sector *j*. Similarly, intermediate inputs can be disaggregated into domestic and imported inputs. Grouping production factors by the level of knowledge incorporated *k* allows us to define the knowledge intensity of sector *j* exports as:

(4)

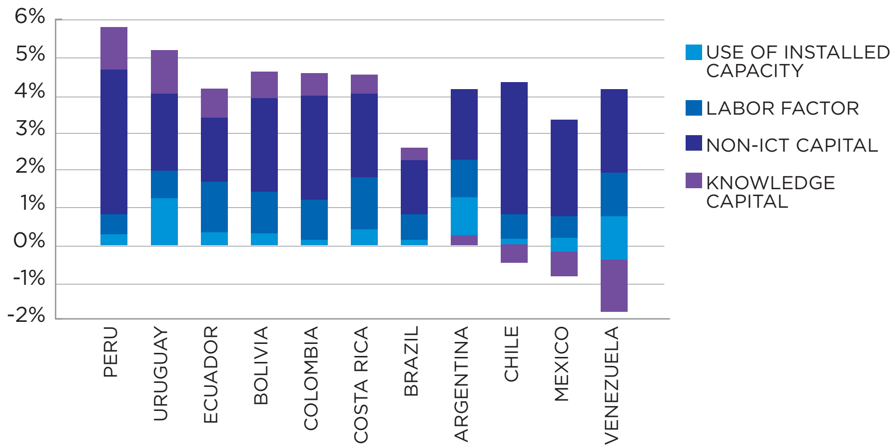
$$I^k = \frac{K_j^k}{p_j^X X_j}, con\ K_j^k =$$
$$\sum_{i=1}^{m} r_{i,j}{}^k K_{i,j}{}^k + \sum_{h=1}^{n} w_{i,j}{}^k L_{i,j}{}^k +$$
$$+ \sum_{l=1}^{p} p_{j,i}^{Mk} M_{i,j}$$

The sum of all sector-specific aggregate values gives the knowledge content of exports. Note that, due to the assumption of proportionality, this is equal to the knowledge intensity of value added plus the knowledge intensity of intermediate inputs.

FIGURE 2

SOURCES OF ECONOMIC GROWTH IN MAJOR COUNTRIES IN LATIN AMERICA (2002–2015)

ANNUAL CONTRIBUTIONS TO GROWTH IN ANNUAL GDP IN %

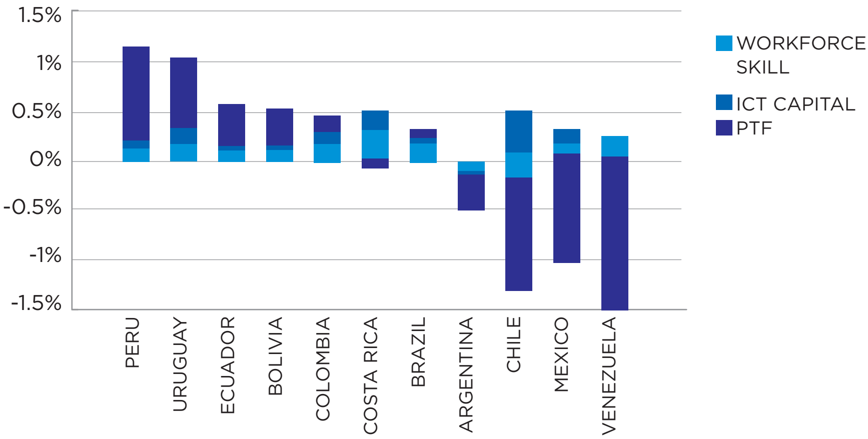


Source: Compiled by the authors based on data from TED and ARKLEMS+LAND.

FIGURE 3

CONTRIBUTION OF RESTRICTED KNOWLEDGE CAPITAL TO ECONOMIC GROWTH BY ASSET TYPE IN MAJOR COUNTRIES IN LATIN AMERICA (2002–2015).

ANNUAL CONTRIBUTIONS TO GROWTH IN GDP IN %



Source: Compiled by the authors based on data from TED and ARKLEMS+LAND.

THE ROAD AHEAD

The essence of our proposal is to tackle the generation and use of innovation in the economic structure by using methodologies that make it possible to compare sectors with the GDP and one another over time. The aim of doing so is to analyze growing economies and compare them internationally to be able to measure the performance Latin American economies against one another and against the rest of the developing world, especially the BRICS countries, and economies and regional blocs in the developed world.

The methodology that best meets these requirements is the expanded knowledge accounting approach that we have put forward here. Valuing knowledge allows us to quantify the effects of innovation on production activity by considering not only the generation of innovations but also the use of these. Knowledge can be compared across sectors, time periods, and countries if it is measured as an asset that generates production services, basing this calculation on the SNAs and then expanding on them to analyze the sustainability of an economy's growth, as we have proposed here. This approach needs to be exhaustive if we wish to diagnose and predict the effects of disruptive innovation on employment and trade, as it requires a detailed breakdown by sector. Different experiences in Argentina would allow us to reconcile and compare existing economic series and to suggest new surveys and statistical procedures.

This study puts forward a methodology for evaluating the impact of innovation and knowledge on production activity, employment, and trade by delimiting and defining knowledge capital as an asset used by production activities that may potentially generate productivity and sustain growth. The methodology that we have proposed allows innovation and knowledge to be measured by expanding the 2008 SNA asset boundary to obtain a metric that is compatible and comparable with GDP.

Investment in knowledge thus includes not only traditional expenditure on scientific R&D but also nonscientific R&D, such as design, and spending on the creation of entertainment and artistic works, training human capital, advertising, and marketing and other assets included in the literature on intangibles.

NOTES

[1] Una 1. A complete version of this article forms part of an IDB/INTAL Technical Note.

[2] Prospective methodologies such as those of Frey and Osborne (2013) and Arntz, Gregory, and Zierahn (2016) are analyzed in other articles of this issue of Integration & Trade (see the articles by Aboal and Zunino, and Pacini and Sartorio).

[3] Coremberg (2010) provides evidence of major gaps in different types of infrastructure between the Argentine economy, developed countries, and the rest of the region, with and without adjusting for efficiency indicators.

[4] In 1994, the OECD revised its classification of manufacturing industries into 22 sectors, which had been established 10 years earlier based on ISIC Rev. 2 To do so, it drew on more up-to-date information to evaluate the intensity of expenditure on R&D. The relevant information was weighted with an indirect intensity indicator by surveying the intensity of R&D content in the capital goods and intermediate goods used by each sector during production (in addition to the traditional indicator of R&D expenditure as a share of turnover in each sector).

5 For a more exhaustive discussion of other examples of discrepancies between the ε and the α, see OECD (2001), Stiroh (2002), and Coremberg (2009).

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FIND OUT MORE ABOUT INTEGRATION 4.0

ANALYSIS

Robert Ivanschitz
and Daniel Korn
Microsoft Latin America

Cloud computing

Restructuring online space

The best way to predict the future is to invent it.

Alan Kay

CLOUD COMPUTING MAY BRING ABOUT A TRUE DISRUPTION IN THE RELATIONSHIP BETWEEN HUMANS AND MACHINES. THE CLOUD IS AN ONLINE SPACE WHERE AUTHORIZED USERS CAN ACCESS ALL KINDS OF DATA THROUGH ANY DEVICE THAT CAN CONNECT TO THE INTERNET. ARTIFICIAL INTELLIGENCE ALLOWS MACHINES TO LEARN DIRECTLY FROM THE CLOUD AND THUS MULTIPLIES THEIR POTENTIAL FOR ABSORBING AND ANALYZING INFORMATION. SOME OF THE LARGEST TECH FIRMS IN THE WORLD HAVE CREATED AN INITIATIVE CALLED THE PARTNERSHIP FOR ARTIFICIAL INTELLIGENCE.

The history of technology—and indeed civilization—is a history of transformative innovations. For our generation, it is cloud computing that is driving a digital transformation. Should we welcome this change? Should we fear it? We have seen these questions before. A century ago, for example, many societies experienced a major revolution as horse-drawn carriages gave way to cars. Many embraced cars because they offered new freedom of mobility, minimizing the time to reach far-away places, opening the door to new industries and new markets. Traditional modes of transport were superseded and traditional jobs gave way to new occupations. But a farrier might not have welcomed those changes.

In 1905, 100,000 horses powered New York City—for local transportation, cargo deliveries, and more. As cars became dominant, the number of horses in the city fell rapidly, and so too did the number of people employed to maintain them, including farriers, stablehands, blacksmiths, and saddle-makers.

Fast forward to today. The rapid pace of technological change driven by the advent of cloud computing is already here—online search, smartphones, apps, and other technologies. As Cesar Cernuda, President of Microsoft Latin America said, "It is not that we're preparing for [the Fourth Industrial Revolution] … I just returned from Brazil where they have more than 100 million Facebook users: *that* is internet, *that* is cloud, *that* is mobile… this digital transformation is something that we're living."[1]

Few will doubt that cloud computing delivers enormous benefits. Through the cloud, consumers are accessing a greater universe of information and services than ever before, businesses are leveraging greater computing power to drive new business models that unlock new markets, and public institutions are becoming more efficient in delivering services to a broader array of citizens (see box). All at a cost that is so accessible that we speak of a giant leap in the democratization of computing.

In short, it is clear that the cloud can change the world for the better. But when we step back and look at the public discourse on cloud-enabled technologies, the sense of excitement is sometimes tempered by trepidation. People are asking a new version of the "farrier's question" of a century ago—how will cloud computing impact employment, and how can we ensure no one is left behind?

THE INCLUSION PRINCIPLE

The first part of the answer is that, as demonstrated in a recent study of census data for England and Wales since 1871, technological progress has consistently been a "great job-creating machine" (Allen, 2015). Cloud computing likewise creates jobs. It drives overall *growth* in employment, in at least three key ways. It stimulates demand for new occupations directly. Cloud computing has already enabled the emergence of new occupations—such as data scientists—generating vast numbers of new vacancies that need to be filled. In late 2014, International Data Corporation predicted that demand for positions in data science, data management, and interpretation would reach nearly a million in the United States alone by 2018 (Vesset et al., 2014). Likewise, in a 2016 survey, 42% of responding employers in the Americas reported jobs shortages for both skilled professionals and IT workers (Orlikowski and Lozinak, 2016).

Cloud computing enables organizations to re-allocate resources and thereby increase employment in other areas. In a recent Rackspace survey of UK and US enterprise cloud users, 62% of respondents indicated they are reinvesting their savings from cloud computing back into the business to do things like increase headcount, boost wages, and drive product innovation (Weaver, 2013). A Boston Consulting Group survey (Michael et al., 2013) of SMEs in five countries, including the United States and Brazil, found that SMEs using cloud technologies grew jobs nearly two times faster than SMEs not in the cloud. The survey also found that within Brazil alone, adoption of new cloud-based and related technologies could boost formal jobs by up to 2.5 million. And *The Economist* (2017) has noted that reductions in costs caused by automation can "actually increase demand [stimulating jobs] ... Despite the introduction of the barcode scanner in supermarkets and the ATM in banks, for example, the number of cashiers and bank tellers has grown."

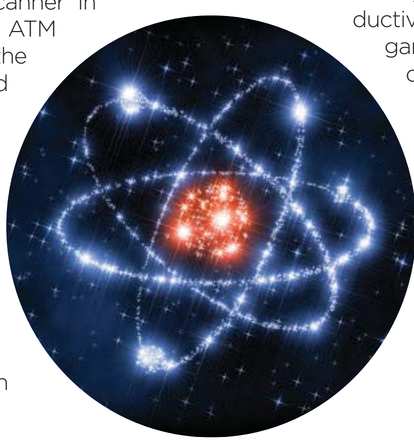
Cloud computing enables the creation of innovative services and accelerates the creation of new companies in the digital economy. For instance, the relatively new mobile ecosystem in Latin America—driven

100 MILLION

THE NUMBER
OF FACEBOOK USERS
IN BRAZIL

by growth in mobile app developers and related service providers relying on cloud infrastructure—already employed as many as 1.9 million people in 2015 (GSMA, 2016). By reducing barriers to entry for new businesses, cloud computing can also help lift people out of poverty. Colombia's former minister of ICT, Diego Molano, credits the Colombian government's initiative to increase the number of Colombian citizens connected to the internet from 2.2 million in 2010 to 8.8 million in 2014 as the reason that 2.5 million citizens were lifted out of poverty during that period (O'Connor, 2014).

Overall, therefore, cloud computing is likely "to be positive [for jobs], creating more jobs than are destroyed and accelerating the creation of new businesses" (The Economist and Intelligence Unit, 2014). These jobs may also be better-quality jobs: a new ILO study concludes that the expanding use of digital technologies to enable work at home and elsewhere could help to improve work-life balance, reduce commuting time, and boost productivity (Eurofound and Organización Internacional del Trabajo, 2017). To promote such "teleworking," the government of Colombia has launched a website that offers companies and workers a wealth of information on teleworking, "including job openings via telework" (Semana, 2015).



BENEFITS FOR THE COMMUNITY

Governments throughout the Americas have started to use this new tool as a way of generating benefits for the community. The following list describes a series of examples in which the benefits of cloud computing go well beyond mere cost savings: 1) By switching to the cloud, Miami's municipal government enabled building inspectors to issue permits while on site by accessing documents remotely, thus speeding up development. 2) Peru's government used the cloud to increase citizen engagement by providing an app that located the nearest polling station for voters. The result was a reduction of nearly 60% in voter absenteeism in 2016 compared to the 2011 presidential elections. 3) The government of Antigua and Barbuda created a Citizen's Portal that, in the words of the minister of information, broadcasting, telecommunications, and information technology, Melford W. Nicholas, increased citizen engagement and provision of services online to include the renewal of driver's licenses, applications for entry visas, and access to the land and company registries at a "reduced cost in terms of total cost of ownership [and with] the additional benefit of it being scalable based on demand."[2] 4) The Tax Authority of Mexico (SAT) optimized one of its most important functions: processing electronic invoices. In 2012, SAT processed 25 million invoices a month. After moving to the cloud, in March 2015, SAT managed to process 35 million invoices in one day.

HELPING THE TRANSITION

Despite these inspiring examples, we should not expect the cloud transformation to be painless or to occur without the right mix of public policies and worker training. Many people today are unable to benefit from the emerging digital economy because they lack the appropriate skills and opportunities to master them (Smith, 2016). The United States, for example, had 600,000 open computing jobs last year but produced only 40,000 new four-year computer science graduates (Code, 2017). In Brazil, 67% of companies identified the lack of qualifications in the current labor force as a key roadblock to higher productivity, while "a whopping 59% of employers in Argentina said that they faced difficulty in finding skilled labor for open positions" (Reeve-Tucker, 2016).

As one of the world's leading cloud providers, Microsoft is working hard to address concerns over the social and economic impacts of cloud computing. One of our key efforts is to promote solutions aiming to ensure that everyone, regardless of socioeconomic status, has affordable access to high-speed internet.

Moreover, through the Microsoft Professional Program, Microsoft has begun training people directly in reskilling needed to work with cloud technologies, Big Data, and internet development. Over 35,000 have enrolled in the program so far (16,000 are from the United States and Canada, and over 2,000 are from Latin America). The first certificates for data science were issued in February 2017 and two new tracks were announced in April 2017 (Big Data Engineering and Front-End Web Development).[2]

Although Microsoft is committed to doing our part, our efforts alone are not enough. To make the transition to the cloud a success, governments must take an active role to prioritize, incentivize, and drive new programs to empower workers to have the skills they need for new occupations. This is one reason why we advocate for governments to expand computer science education in schools, and to undertake other policies—from adult education to increasing broadband access in rural areas—to help skill up, retrain, and empower workforces.

THE MAJOR LEAGUE

Even as governments lead, however, it is important that all stakeholders—including industry groups, educators, and NGOs—support those efforts. For example, companies in our sector have gotten together to establish the *Partnership on AI to Benefit People and Society,* a nonprofit with a mission to ensure that artificial intelligence (AI), built on top of cloud infrastructure, is harnessed for the benefit of us all.[3] As noted by Microsoft research technical fellow Eric Horvitz, who is also the co-chair of the project, "the influence of AI on jobs and economics more broadly is one of the planned thematic pillars of efforts for the *Partnership on AI."* [4]

The fact is that many jobs will be lost to robots, self-driving cars, and other computer-enabled innovations,[5] so investments in training that prepares people for new high-demand jobs in science, technology, engineering, and mathematics (STEM) is one of the most important actions we can take. Governments should also invest in high-quality worker retraining programs for those already in the workforce.[6]

As Brad Smith, president of Microsoft has said, "in a time of rapid change, we need to innovate to promote inclusive economic growth that helps everyone move forward. This requires a shared responsibility among those in government, across the private sector, and by individuals themselves" (Smith, 2016). With thoughtful efforts and public-private collaborations, the transformation of our time can truly change people's lives for the better.

NOTES

[1] Interview of Cesar Cernuda by Xavier Serbia, CNN Dinero, CNN en Español (October 28, 2016).

Interview with Hon. Melford W. Nicholas, Minister of Information, Broadcasting, Telecommunications, and Information Technology, Antigua y Barbuda, February 13, 2017.

Interview with Keith Boyd, Director of Business Strategy, Microsoft Professional Program (March 3, 2017); see also http://academy.microsoft.com/.

See Partnership on AI to Benefit People and Society, available at https://www.partnershiponai.org/.

Interview with Eric Horvitz, Technical Fellow and Director at Microsoft Research, Redmond Lab, Microsoft Corporation, March 7, 2017.

The World Economic Forum's *Future of Jobs* report, for instance, indicates that the biggest employment decline of any job family is expected in current Office and Administrative roles, since the latest technological trends have the potential to make many of those roles redundant.

See Statement of Eric Horvitz before the Committee on Commerce, Subcommittee on Space, Science, and Competitiveness, United States Senate, "Hearing on the Dawn of Artificial Intelligence," (November 30, 2016).

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How we can prevent technological unemployment from worsening social inequality in the region. New forms of work and education and the debate around a universal basic income.


DIGITAL
INCLUSION

The future has many names: For the weak, it means the unattainable. For the fearful, it means the unknown. For the courageous, it means opportunity.

Victor Hugo

Carmen Pagés and Laura Ripani
Inter-American Development Bank

Employment in the fourth industrial revolution

The world is entering what has come to be known as the Fourth Industrial Revolution. While the first was born with the introduction of the steam engine in manufacturing and the second with the discovery of electricity, the third and fourth have been marked by the massive development and application of information and communication technologies, and in this latest stage, by the confluence and fusion of the latter with a wide array of new technologies, such as artificial intelligence, big data, the cloud, 3D printing, the Internet of Things, and blockchains (Schwab, 2016). These changes are driving incredible transformations in the world of work that are enabling us to be more connected, mobile, and ubiquitous than ever before.

These changes are driving incredible transformations in the world of work that are enabling us to be more connected, mobile, and ubiquitous than ever before. At the same time, as we move further into this Fourth Industrial Revolution, in which technological advances are ever more rapid and profound, concerns about the future of the labor market are multiplying. Will robots put an end to our jobs? Which jobs are more susceptible to automation? How can we prepare ourselves to successfully compete in the labor market of the future? What role should the state play in improving the future of work?

THE FOURTH INDUSTRIAL REVOLUTION

The Potential for Automation

The past 10 years have witnessed the rapid development of machinery that is at both powerful and precise, capable of performing more activities autonomously at a lower cost than it would take to hire a worker. Added to the now ubiquitous computers and communication technologies are robots, defined by the International Federation of Robotics (IFR) as automatically controlled, reprogrammable, multipurpose machines. In just over 20 years, the use of robots in the United States and Europe has increased 400%–500%, with especially high growth in the electrical, electronics, plastics, metal, and machinery industries (IFR, 2016). The automation of services is also growing, notable examples being product distribution warehouses operated exclusively by robots, stores with no cashiers (Amazon), and fully automated restaurants (for example, Eatsa in Los Angeles). Given the savings in labor costs, many more distribution centers, stores, and restaurants will likely embrace automation. Added to this is the breathtaking development of artificial intelligence (IA)—that is, machines that imitate human cognitive functions (for example, learning and problem solving, understanding human language, successfully competing against world chess champions, driving cars, and diagnosing illnesses—functions that only a few years ago were considered something that only human beings could perform).

These advances make the potential for automation enormous. According to an Oxford University study (Frey and Osborne, 2017), 47% of jobs may be fully automated in the next 20 years. Another study by McKinsey and Company (Manyika et al., 2017) indicates that in the United States alone, automatable activities currently constitute 51% of the economy's activities, representing US$2.7 billion in wages. Globally, automation could affect 49% of the world's economy, or 1.1 billion workers and US$12.7 billion in wages (Manyika et al., 2017). It is also estimated that, as a result of automation and AI, half the occupations that exist today could disappear by 2025.

The Increase in Mobility and Flexibility

Advances in communication mean that many people no longer have to work in an office today. All they need is an internet connection. In his book *The Future of Work*, Jacob Morgan states that the jobs of the future will be characterized by a flexible work environment, in which people can work from anywhere and at any time; can collaborate and communicate in different ways; and can continue learning throughout their working lives through a wide range of virtual mechanisms. Many organizations are now redesigning their workspace to account for this, cutting back on the number of offices and bearing in mind that while some employees spend most of their time at the office, many others only come in a couple of days per week, and when they do, they use common areas shared with other "nomad" employees. Another trend along these lines is workspace that an individual or company flexibly rents by the day or by the hour.

1.1 BILLION

WORKERS MAY BE AFFECTED BY AUTOMATION THROUGHOUT THE WORLD

Changing jobs more frequently is another growing trend. According to the Bureau of Labor Statistics (2015), in the United States, the average baby boomer (born between 1957 and 1964) held 11.7 jobs in a 30-year period. That same study indicates that millennials (people born after 1980) will change jobs every two years or less.

Digital Platforms and the Freelance Economy

Traditionally, businesses have existed as a way of lowering transaction costs; until recently, it was usually easier to produce goods and services if many parts of the process were controlled by the same company because it facilitated the transactions involved in the process. Today, however, information and communication technologies have drastically reduced these costs, and many tasks that until recently had been considered core production activities are now beginning to be outsourced—a trend that will increase in the future. Hence, the rise of the freelance economy, where businesses can hire people to perform

specific work for an activity or project through digital platforms. Workers, therefore, are no longer company employees but contractors. Companies such as Uber, Upwork, etc. show that business models based on this type of hiring can be successful. There are no official statistics on how many workers engage in this type of work, but according to *The Wall Street Journal*, one out of three workers in the United States is a freelancer and up to 40% will be by 2020 (Freelancers Union and UpWork, 2016).

THE END OF WORK?

A series of authors have expressed alarm about the potential end of work. In an influential book, Brynjolfsson and McAfee (2011) wonder whether technology will put an end to work and all the benefits commonly associated with having a job (for example, having the right to a pension and health insurance). They argue that we are in the throes of an unprecedented technological revolution in which change is rapidly accelerating. If machines are capable of doing work better and more economically, what awaits humanity? Is technology condemning us to mass unemployment and inequality?

Technology obviously has enormous potential to destroy jobs, but what will be its overall effect? To anticipate how technology will impact the level and composition of employment, several issues should be considered.

First, technology tends to replace the most routine tasks and not necessarily all the work that a person does. A job consists of a series of tasks. The distinction between "work" and "task" is key because technology can *replace* some tasks and *complement* others. The tasks most likely to be replaced by technology are those that are more repetitive and easily automated (Autor, 2015). Nonetheless, the fact is (at least for now) that few occupations can be fully automated. According to Manyika et al. (2017), less than 5% of current jobs can be fully automated. That being said, in 60% of jobs, almost one-third of the tasks (30%) can be automated. Recent studies show that in the United States and other advanced economies, there has been a significant decline in jobs that are based on more routine tasks (Autor, Katz, and Kearney, 2006; Goos, Manning, and Salomons, 2014).

Second, technology has made occupations based on less-routine tasks more valuable. This is leading to polarization of the labor market, with growing demand for two types of occupations at opposite ends of the wage distribution (Autor et al., 2006). On the one hand, jobs and wages are increasing in occupations based on nonroutine cognitive tasks (computer specialists, engineers and technicians, and workers whose work becomes more valuable with the introduction of technology). These occupations tend to be at the high end of the wage distribution (Autor et al., 2006; Acemoglu and Autor, 2011, Goos et al., 2014).

2%

THE ANNUAL INCREASE IN BANKING SECTOR JOBS DESPITE THE INTRODUCTION OF ATMS

On the other hand, the demand for labor in nonroutine manual jobs that are not easily automated and often performed by people with low levels of education for very little pay (for example, personal services), is rising, while the demand for labor in occupations in the middle of the wage scale, which are precisely jobs characterized by more routine tasks, is falling.

Brynjolfsson and McAfee (2011) predict that this trend will accelerate as time goes on, since it will affect not only workers whose jobs consist of routine tasks, but many others whose work will be automatable in the not-too-distant future, both at the high end of the education distribution (translators, data analysts, manager, etc.) and the low end (for example, car and truck drivers). If not countered by policy action, these trends will exacerbate the growing income gap between the wealthiest and poorest members of society.

A final point that should also be considered is the fact that the introduction of technology lowers the cost of producing many goods and services, which will generate employment in at least some industries. Thus, for example, as documented by James Bessen, the mass use of automatic teller machines (ATMs) has not meant the end of employees in the banking sector, whose numbers, on the contrary, have risen by 2% per year. Why? Bessen (2015) documents that on the one hand, ATMs have freed employees from their most routine tasks, shifting their work from simple teller transactions to processing credit applications and investments for clients. Even more importantly, however, the use of ATMs has drastically reduced the cost of opening new branch offices. Thus, while the ratio of employees per branch office has fallen, the number of branch offices has substantially increased—enough for employment in the banking sector to increase as well.

Is the banking sector the exception that proves the rule? A new study by James Bessen (2016) confirms that between 1980 and 2013, the sectors that introduced more information and communication technology had larger gains in employment. This confirms the historical trend in which the introduction of technology over the centuries has not reduced the percentage of the population that works. On the contrary, that percentage has been increasing in virtually every country, coinciding with the mass influx of women into the labor market

The big question is whether this time things will be different. Brynjolfsson and McAfee (2011) predict that history will not be a good indicator because the speed and magnitude of the technological change that we are experiencing means that its effects will be hard to avoid. In a recently published study, Acemoglu and Restrepo (2017) examine the impact of the introduction of robots in US manufacturing. The findings are not encouraging: their verdict is that, unlike information technology, the introduc-

40%
OF WORKERS IN THE UNITED STATES WILL BE FREELANCERS BY 2020

tion of industrial robots has a negative impact on both the demand for labor and wages. In this case, the negative effects of job loss are greater than the positive effects on employment stemming from the lower cost of producing goods and services. For now, the net job loss has been small, for while the prevalence of robots has substantially increased, it is still low. Nevertheless, everything seems to indicate that robotization will become increasingly widespread in the coming years. It is possible that the positive effect on employment stemming from the lower cost of goods and services and the shifting of labor to less-routine tasks (as occurred in the banking sector) has not yet been observed and thus their effect has been overestimated. Even so, this study shows that the disruptions in employment may be rather substantial.

Another important and related aspect to consider is whether the new job opportunities created by the introduction of technology are capable of satisfactorily employing the workers displaced by these changes. Here, the verdict is also uncertain. In the case of the United States, Autor and Dorn (2006) show that many people who lost their jobs due to the introduction of information and communication technologies were forced to take less-skilled work (at the lower end of the wage distribution). Only a few were able to make the leap to equally or more sophisticated or higher-paying jobs. These authors also document that older workers were those hurt the most by technological change.

The answer to whether automation will necessarily result in a drop in the proportion of people who work or will simply lead to the transformation of jobs is being written right now. Everything indicates that many jobs (particularly the most routine) will be destroyed and other completely new ones—many of them still undreamed of—will be created. However, the pace at which the destruction will be accompanied by job creation will depend on the speed of change and economies' capacity to retrain and move workers from declining to emerging activities. Without intervention, these changes are expected to continue exerting pressure toward greater income inequality.

A final question is whether the trend toward "Uberized" employment, or freelancing, will mean the end of salaried employment as we know it—that is jobs with benefits. A recent study by Oxford University warns that while this new type of employment can open up opportunities for work and generate income for many, it can also lead to social isolation, lack of a work/life balance, and problems with unscrupulous middlemen (Graham et al., 2017). Most workers in this new economy do not enjoy the protections established in the labor codes for salaried employees; instead, most of them work as independent contractors, without the right to social security, vacations, or other employment benefits. Intensification of this trend as time goes by will make it harder to guarantee health or pension protections for most workers through the labor market.

DEVELOPING ECONOMIES

The trends described above have been studied largely for the developed economies, but what about the impact on developing economies? From the technology standpoint, the World Bank (2016) estimates that two-thirds of the jobs in emerging and developing countries can be automated. In the Latin American and Caribbean context, some countries in South America are at the top of the list when it comes to the potential for automation (highest on the global list, for example, are Argentina and Uruguay, where 60% or more of jobs could be automated). In Central America, around 40% of jobs in many countries could be automated. It is unclear, however, whether these jobs actually will be automated, since these effects will be moderated by the lower cost of labor relative to capital and the slower introduction of technology.

Less than one in ten poor households has an internet connection (World Bank, 2016), and only seven in ten people in the lowest income quintile of the population in developing countries has a cell phone that can be used to access the internet. Moreover, there is a wide gap between the region and the advanced economies in terms of the availability and use of digital technologies by business (World Bank, 2016). The expanded use of technology is hindered by the vast number of unproductive small businesses, which have been slow to upgrade their technology. In addition, broadband penetration in Latin America and the Caribbean is far behind that of the developed countries, even with rapid growth of 16%-18% annually (DigiLAC, 2014). It is perhaps because of the low penetration of technology that recent studies show few indications of automation in the labor market (Corporación Andina de Fomento, 2017).

Another trend that is barely visible yet in the region but is likely to heavily impact the emerging countries is the development of the freelance economy. This mode of employment will foster job creation, enabling workers in the region to connect with markets in developed countries. In fact, today many people in South Africa, Vietnam, Malaysia, India, and the Philippines already design websites, process data, translate documents, etc. to meet demand in developed countries. The main business flows in Latin America and Caribbean are seen in Argentina, Colombia, Brazil, and Mexico (Graham et al., 2017). Everything indicates that the demand for this type of work will soar in the future; however, the number of people who will be connected (and willing to do this type of work) will also multiply. It is therefore possible that with the creation of a global market and competition among different countries to meet demand, employment conditions will deteriorate in the future.

HOW TO PREPARE FOR THE FUTURE OF WORK

The changes associated with the Fourth Industrial Revolution are profound and require an effort not only by individuals but also by the private sector and the state to capitalize on their benefits and mitigate the potential costs in terms of well-being and inequality.

From the standpoint of individual workers, the trends described indicate that to be a winner in this new market, it will be necessary to invest in developing nonroutine skills that are enhanced by technology. A study by the Organisation for Economic Co-operation and Development (2016) states that eight out of every ten new jobs in developing countries are for knowledge workers (professionals with technical skills, practical training, management skills, and an enterprising spirit). Given how rapid technological change is, education in our youth will not be enough: everyone must continue investing in education and training throughout their life.

Recent studies also show that, in addition to demanding the skills specific to an occupation, businesses are looking for people with problem-solving capabilities and good social skills, which are what distinguish us from robots: creativity, effective communication, empathy, and a proactive mindset. The ability to deal with emotions is currently our advantage over machines. Thus, for example, while it will soon be common for artificial intelligence to diagnose our illnesses more efficiently than the best doctor, we will continue to want our doctors and other caregivers to be human and have the empathy necessary to deal with our emotions. Today leadership skills, persistence in the face of adversity, initiative, and responsibility are also determinants of success in the labor market, and they will become even more important over time as robots take over the most mechanical and repetitive aspects of our work.

Likewise, the winners will be people who, in addition to possessing social skills, can understand and use technology. Hence, it will be increasingly important to invest in acquiring digital skills, such as coding, managing social networks with a business slant, working virtually in digital platforms, and analyzing big data to extract relevant information from the vast quantity of data produced every day on social networks and the internet.

Returning to Latin America and the Caribbean and other emerging regions, if the growing demand for skills (cognitive, technical, and social) materializes in the region, it could result in major bottlenecks to personal and national development. Due to the glaring weaknesses of the educational systems in many developing countries, the population is unprepared for these changes. The PISA achievement test in the region showed that 48% of students could not understand a basic text and 62% could not perform a simple calculation. These young—and not so young—people will have serious problems continuing their training beyond the formal educational setting since vocational training systems in the region are divorced from the needs of the market. Finally, businesses are also unprepared to redefine positions and train people, and the capacity of states is still very limited. When people lose their jobs today, they end up working in the informal sector (Alaimo, Bosch, Kaplan et al., 2015).

For all these reasons, we must invest in the development of better vocational training systems that will help people continuously upgrade their skills to achieve more relevant, higher-quality skills. To do so, we must continue to improve quality assurance systems, heavily emphasizing the accreditation of training institutions and the evaluation of results, and we must invest in the quality of professors and instructors. Concerning the relevance of the training, we must continue to make curricula more relevant, which means investing in instruments for anticipating skills demand (statistical models, business surveys, and the use of big data) for policy-making (Gonzalez-Veolia and Gucci, 2016). The state must also get employers far more involved in identifying skills demand and providing training through different types of on-the-job training, such as apprenticeship programs, forging public-private partnerships for skill building. Although this implies resources, it should be recalled that the system currently invests countless resources whose cost-effectiveness can be improved (Huneeus, De Mendoza, and Rucci, 2013).

Another idea that is gaining ground is the need to redistribute the enormous potential income that will be generated by automation. Bill Gates recently proposed a tax on robots (Kessler, 2017). Others have proposed the creation of a universal basic income that would enable everyone in a country to receive a certain sum of money regularly and unconditionally, regardless of whether a person is rich or poor or whom he or she lives with.

Furthermore, the growing trend toward the use of freelance mechanisms will require the strengthening of health, old age, and unemployment insurance, regardless of a person's employment status. It will also be necessary to find suitable ways of regulating this new industry, seeking, on the one hand, to promote innovation and, on the other, to create decent employment conditions.

48%

OF YOUNG PEOPLE IN LATIN AMERICA AND THE CARIBBEAN HAVE PROBLEMS UNDERSTANDING BASIC TEXTS

What we ultimately need is a new model based on a new social contract that places much more emphasis on democratizing opportunities so that we can all enjoy the benefits of technology while also compensating and supporting those who are adversely affected, so that they can get back on the right track. Otherwise, the gap between those who are in a position to make it in this new world and those who are not will continue to widen, and Latin American and other emerging countries may remain on the margins of this new industrial revolution.

Flexibility, independence, collaboration, networks, and technological innovation are all words that describe the jobs of the future, but unemployment, vulnerability, and inequality may as well. The countries of the region and other emerging countries need to prepare themselves now to face up to these risks and make the most of this new era.

NOTES

[1] From 0.3 robots per 1,000 workers in 2003 to 1.7 in 2015 in the United States, and from 0.6 to 2.5 in Europe (Acemoglu and Restrepo, 2017)

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ANALYSIS

White-collar unemployment

Soft skills and routine work

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No man should have to do a job
that a machine could do.

Henry Ford

A TRADITIONAL VIEW OF TECHNOLOGICAL CHANGE AND THE LABOR MARKET IS THAT WHILE BLUE-COLLAR WORK IS AT RISK OF AUTOMATION, WHITE-COLLAR WORK IS NOT. THIS ARTICLE DESCRIBES WHY THIS VIEW IS NO LONGER CORRECT.

A traditional view of technological change and the labor market is that while blue-collar work is at risk of automation, white-collar work is not. In this article I describe why this view is no longer correct. My co-author, Richard Susskind, and I explored many of the ideas in this article in our book, The Future of the Professions (2015). In the year that followed its original publication we had the opportunity to test and debate these ideas around the world, presenting our work in over 20 countries, at more than 100 events, to around 15,000 people.

Simply put, the central argument of The Future of the Professions is that there are two futures for white-collar workers. The first future is a reassuringly familiar one—it is a more productive version of what we have today. Here white-collar workers use technology, but simply to perform the tasks and activities that they already carry out more efficiently and more effectively. The second future is very different—here, technology does not simply make white-collar workers more productive, but actively displaces those workers from certain tasks and activities. In turn, these tasks and activities are either performed by different types of people or, in many cases, not by people at all. In the medium-run, we anticipate these two futures will develop in parallel. In the longer-run, we anticipate that the second future will dominate.

As we note in the preface to the paperback edition of The Future of the Professions, the reaction to our work has been mixed. More often than not, it has had a polarizing effect—there are those who violently agree, and others who reject it with equal enthusiasm. In the book, we explore eight professions. Speaking in general terms, we describe how accountants are largely receptive, lawyers are mostly conservative, journalists are resigned, teachers are suspicious or evangelical, doctors notably dismissive of nondoctors having any sort of view on their future, architects are excited about the possibilities, consultants see the possibilities in industries other than their own, and the clergy are notably silent.

This article builds on this work and the thinking we develop in it. It is in four parts. First, I explore the origins of this traditional view of technology and the labor market—that blue-collar work is at risk, but white-collar work is not. I suggest that its intellectual roots lie in the "skills-biased" view of technological change, an outlook that, in the 1990s, dominated economic thinking, and remains influential today. Then I set out the nature of recent technological change—growth in available processing power, improvements in data-storage capabilities, and advances in algorithm design—and explain why our systems and machines are becoming increasingly capable. Thirdly, I explore two central arguments for why white-collar work is no longer immune from technological change. Finally, I close with what this ought to mean for current and aspiring white-collar workers, and for public policy.

THE BIAS TOWARD SKILLED LABOR

A traditional view of technological change, noted at the start of this article, is that while blue-collar work is at risk of automation, white-collar work is not. Historical trends in the labor market, and the

Moore's Law

IN 1965, MOORE PREDICTED THAT CHIP CAPACITY WOULD DOUBLE EVERY TWO YEARS

arguments that were developed by economists to interpret and understand these trends, help to explain why this traditional view became so widespread.

For a large part of the 20th century, the relative wage of those with a college-equivalent education compared to those with only a high school equivalent level of education rose around the developed world, a phenomenon known as the skill premium. Of course, the extent to which the skill premium rose changed over time and place. But the general trend was one in which the "price" of skilled workers appeared to rise relative to the "price" of low-skilled workers, each measured by their respective wages.

A consensus emerged among economists that technology had an important part to play in understanding and explaining these trends. In particular, the claim was that technology was "skill-biased"—it favored, or was biased toward, those who had skills over those who did not. Put more simply, technology made the work that skilled workers did more important and more valuable as compared to the work done by those with fewer skills. The "skill-biased technical change" thesis was used to explain the trends in wages in a wide variety of developed countries (see, for example, Bekman, Bound, and Machin, 1998, and Acemoglu, 2002).

The skill-biased technical change thesis was not only used to interpret what was happening in labor markets around the world but also to inform and shape the policy prescriptions that policymakers thought it would be appropriate to respond with. The idea was that there was a race between technology and education—a view reflected in the title of Goldin and Katz's (2008) book. Technological change was making skilled work more valuable and so the implication for policymakers was to design a range of interventions that would upskill the workforce. The particular challenge for policymakers was to try and do it fast enough for labor to be able to keep up in this race. The importance that governments around the world attached to receiving a college or university education, for instance, reflected this understanding of what was taking place and what an appropriate policy response ought to be.

This historical experience, and the rising skills premium, appears to support the traditional view that white-collar work is protected from technological change. For large parts of the 20th century, technological change appeared to make the work of white-collar workers more important and more valuable relative to blue-collar workers. While this may be a useful account of what happened in parts of the 20th century it is not necessarily a good guide to the 21st century. That technological change appeared to help high-skilled workers relative to low-skilled workers in the past is no guarantee that white-collar workers will be protected from technological change in the future. Before turning to look at two arguments why this is unlikely to be the case, it is helpful to review the nature of the remarkable technological advances that have taken place over the last few decades.

THE NATURE OF TECHNOLOGICAL CHANGE

In popular commentary on the future of work, the scale and pace of technological change are often captured with reference to Moore's Law. In 1965, three years before he co-founded Intel, a computer scientist called Gordon Moore predicted that the approximate number of transistors we could fit on a silicon chip would double every two years or so. In the 50 years since, this prediction has largely held true, albeit going faster in some periods and slower in others. This technical feat of engineering drove the remarkable growth in processing power that took place over that same period. In 2001, Michael Spence, a Nobel laureate in economics, noted how Moore's Law had resulted in a "roughly 10-billion-times" reduction in the cost of processing power in the 50 years until then—and that observation itself was made 16 years ago. This process continues today and, since then, this doubling has roughly continued every two years.

There is increasing skepticism about whether Moore's Law will continue to hold in the future. Many of these skeptics point, correctly, to the fact that there must be physical limits to the number of transistors that can fit on a chip. And this is clearly right. But it is important to be clear that many computer scientists who anticipate that Moore's Law will continue in the future are not necessarily committed to the traditional way in which this growth in processing power has been achieved—namely fitting ever-shrinking transistors onto silicon-biased integration circuits. It is conceivable that Moore's Law will be maintained in the future by altogether different approaches to computation. The particular techniques that we adopt may not even have been invented yet.

In any event, Moore's Law is only one part of the story. A common mistake made

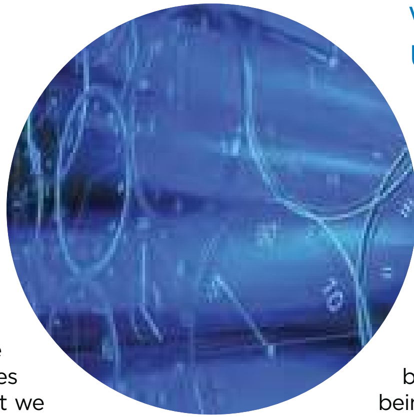
Big Data

THE SAME AMOUNT OF INFORMATION IS NOW CREATED EACH DAY AS WAS STORED IN 2000 YEARS

by popular commentary on the future of work is to focus only on the growth in the raw processing power of these systems and machines. However, these systems are not only more powerful in a computational sense, they are also increasingly capable. Put more carefully, these systems and machines are able to perform an increasing range of tasks and activities, many of which it was traditionally thought only human beings could perform. Of course, the extraordinary growth in processing power is one important driver of this increase in capability. But there are two other important reasons.

The first reason is our ability to capture and store vast bodies of data. At present, there is a great deal of excitement and commentary about data science—otherwise known as "big data," "predictive analytics," and "data analytics." These terms largely refer to the same phenomenon. In 2010, Google's Chairman Eric Schmidt claimed we now create as much information every day as was created between the dawn of civilization until 2003. In *The Future of the Professions,* we estimate that by 2020 this same quantity of information will be created every few hours. This is a natural consequence of the fact that, as more of what we do becomes digitized, all our actions and decisions leave thick "data exhaust" behind them, a growing amount of which we are now able to capture and store.

Alongside these improvements in data storage capability lies the second reason—significant advances in algorithm design. Recent advances in machine capability are not simply due to the fact that systems are more powerful. Nor are they due to the fact that we have growing bodies of data on



which to draw. It is also the fact that we have made significant intellectual progress in algorithm design, in the routines that these systems and machines follow, which means that we can put this processing power and this data to use. Together these three reasons—improvements in computational power, data storage capability, and algorithm design—are driving the capability of today's machines.

LAWYERS AND ACCOUNTANTS

Until recently, many white-collar workers imagined that their work was largely immune from this technological change. In conducting research for our book, many professionals expressed doubt around whether technology can displace human beings or enable less expert human beings to perform at their level. The historical experience of technological change, as noted before, and its apparent skill bias, appeared to give this belief some support.

But an important question follows—why is technological change skill-biased, if it is at all? Put another way, what is it about technological change that means it makes the work of skilled, white-collar human beings, more valuable relative to low-skilled blue-collar workers? The most common explanation is that white-collar work is somehow more complex or more difficult than blue-collar work. It is commonplace, for example, for a lawyer to claim that his or her work requires judgment, for an architect to argue that his or her work requires creativity, or a doctor to stress that his or her work requires empathy; and in turn, that these are capabilities that cannot be performed by a machine.

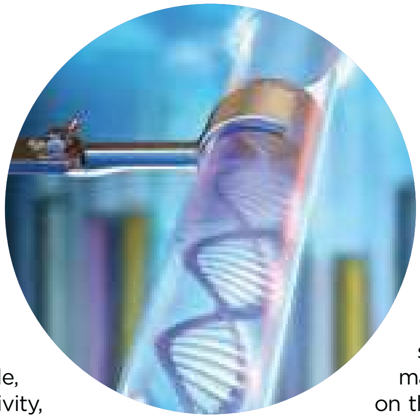
And yet this explanation, though common and intuitive, often stands in stark contrast to what we see unfolding around us today. Almost daily there are new accounts of particular tasks and activities that were traditionally performed by white-collar workers being automated. There are systems that can now compile legal documents, generate designs for buildings and objects, and diagnose illnesses—very often without the input of a traditional lawyer, architect, or doctor. And this is true not only in the law, or in architecture, or in medicine. *The Future of the Professions* documents how, in a wide variety of white-collar settings, technological change is starting to impinge on tasks and activities that many people have traditionally imagined were out of reach.

It follows that the challenge is to explain why this traditional view of technological change is incorrect—why is white-collar work, contrary to expectation, now being automated? Put another way, why were white-collar workers wrong to imagine that their work was immune from technological change? There are two related reasons for this. The first is based on a misunderstanding about the nature of work. The second is based on a misunderstanding about the how the latest generation of systems and machines operate. I now consider each of these in turn.

Tasks, not Jobs

Many people view the jobs that people do as monolithic, indivisible lumps of "stuff." This view is supported by popular commentary on the future of work. In these accounts, we are encouraged to imagine a future where, one day, a worker will arrive at his or her desk to find that their job has been entirely replaced by a robot. It is rare, for instance, to read an article about the future of work, or to watch a news report about automation, which is not accompanied by an image of a robot—perhaps clad in a lawyer's gown or with a doctor's stethoscope around their neck—performing the job of human being in its entirety.

It is clear why this view of work encourages us to imagine that white-collar work is hard to automate. When jobs are considered to be indivisible, monolithic lumps of activity, this strongly suggests, as emphasized before, that the only way for technological change to affect white-collar work is to automate *all* of what a professional does. And so, if professional work is characterized by faculties like "judgment," "empathy," and "creativity"—which, it is said, are hard to automate—it is therefore hard to imagine how white-collar work could be automated.



Yet this view is clearly mistaken. A job is not an indivisible, monolithic lump of stuff. In fact, any given job is made up of a wide variety of tasks. Put differently, any given professional performs a wide variety of different activities in their job. In the economic literature, the "task-based approach to labor markets" has built on and formalized this intuitive observation (see, for example, Autor, 2013). Indeed, the idea behind adopting the task-based approach was developed by my co-author, Richard Susskind, after analyzing legal work from the mid-1990s onwards (see, for example, Susskind 1996, 2000, and 2008). And this more nuanced view of the nature of work allows for a far subtler understanding of how technological change affects the labor market. When professional work is decomposed or disaggregated, and broken down into its composite tasks, it turns out that parts of this work are often relatively straightforward and process-based. Not everything that white-collar workers do, and in certain cases not much, requires creativity, or judgment, or empathy.

To use more formal terms, when professional work is broken down into its composite tasks and activities it transpires that many tasks are routine. This does not mean that they are commonplace or dull. It means that human beings find it relatively easy to explain the particular rules that they follow in performing those tasks. Given that these rules are easy to articulate, it is therefore easy to set out a similar set of rules for machines to follow based on these explanations. In the economics literature, the observation that routine tasks are easiest to automate is known as the "routinization hypothesis" (see, for example, Autor, Levy, and Murnane, 2003).

A common reaction to the claim that white-collar work might be automated is to point to tasks and activities performed by professionals that are difficult to automate, and argue that because these tasks and activities cannot be automated then the rest of what that professional does is also safe from automation. We call this the "argument from hard cases"—and this discussion explains why this particular form of argument is misleading. Of course, it may not be possible yet to automate certain tasks. But the work that white-collar workers perform is made up of a diverse range of activities, and to focus on these cases is often to focus on the atypical, and to paint professional work as uniformly complex when in practice it is often not.

Nonroutine Tasks

The previous argument is that white-collar work, when broken down into its constituent activities, often has a routine task component that is relatively straightforward to automate. This is one reason why white-collar work is at risk of automation. But there is also a second reason—that nonroutine tasks can, increasingly, be automated. Indeed, many of the most striking cases of automation in white-collar work concern nonroutine rather than routine tasks.

In thinking about the capabilities of technology, it is tempting to claim that because machines cannot "think" like a human being they cannot be creative, because machines cannot "feel" like a human being they cannot be empathetic, or because machines cannot reason like a human being they cannot exercise "judgment." But each of these claims is an example of the so-called AI fallacy: it depends upon the view that the only way to get machines to outperform human beings is to copy the thinking process of human beings. The error here is not recognizing that the latest wave of AI systems do not replicate human thinking or reasoning.

Instead, human professionals are being outgunned by brute-force processing power, massive data storage capability, and sophisticated algorithms. When systems predict the likely decisions of courts more accurately than lawyers, or machines make better medical diagnoses on the strength of past medical data rather than on medical science, we are witnessing high-performing, unthinking machines that do not rely on creativity, or judgment, or empathy like a human being. They are following rules that, in many cases, do not resemble the ones that human beings follow.

The AI fallacy also lies at the core of the routinization hypothesis. This hypothesis states that it is straightforward to automate routine tasks since human beings can easily articulate the rules that they follow in performing these tasks, and so it is easy to draw up rules based on this articulation for a machine to follow—and, conversely, that it is hard to automate nonroutine tasks because the rules that human beings follow are not clear. But this ignores the fact that there are other ways to develop systems to perform tasks at the level of experts or higher *without* trying to replicate the thinking processes of human specialists. Put another way, it does not matter if a human being cannot explain the rules they follow in performing a task if the rules that a machine follows in performing that same task are different to the rules that human beings follow.

129,450

SKIN CANCER CASES WERE ANALYZED IN A SINGLE GO BY A DERMATOLOGY ALGORITHM

To see this in practice, consider one white-collar task that many people have traditionally considered to be out of reach of automation—diagnosing an illness. It is often said by doctors and physicians that the skill of diagnosing an illness cannot be written down or easily expressed—it relies upon, for instance, "experience," "instinct," "intuition," and "judgment." And because of this, it is also said that it is not possible to automate it. The spirit of the argument is clear—if we, human experts, cannot even articulate how we perform the task, how can we get a machine to perform it in our place?

The answer is by performing the task in a fundamentally different way to a human being, without relying upon a clear account of the rules that human beings follow in diagnosing an illness. Esteva et al. (2017) describe a system that can predict as accurately as 21 dermatologists whether a picture of a skin discoloration is cancerous. This system does not try to uncover the thinking process that the dermatologist follows in diagnosing a melanoma. Instead, it is performing the task in a fundamentally different way—training a machine-learning algorithm on almost 129,450 past cases to derive a very different set of rules to human beings.

Note that this ability to perform tasks and activities performed by white-collar workers is a relatively recent phenomenon. Only a few decades ago, before the growth in processing power and data storage capacity, it was not possible to operate these systems and machines. Until then, the only way to outperform a human being was to try and copy their thinking process and get a machine to follow it. This is no longer the case.

COMPETING WITH MACHINES?

The argument developed in this article is as follows. First, it is commonly supposed

THE ARTIFICIAL INTELLIGENCE FALLACY

The bestselling book by Richard Susskind and Daniel Susskind, *The Future of Professions*, claims that the argument that nonroutine tasks are not automatable rests on an erroneous idea that the authors dub the "artificial intelligence (AI) fallacy." They summarize this fallacy as follows: "the mistaken supposition that the only way to develop systems that perform tasks at the level of experts or higher is to replicate the thinking processes of human specialists." In fact, machines can achieve better results than humans without needing to carry out the same processes as human beings, simply by analyzing data.

that white-collar work is a monolithic, indivisible lump of work. But in practice, white-collar work can often be broken down into many different types of tasks and activities—and it transpires that many of these are not so complex after all, but are often routine or process-based and can readily be automated. Secondly, it is commonly supposed that those tasks that are nonroutine—those that, for instance, require judgment, creativity, or empathy—cannot be automated. But this rests on the AI fallacy, the mistaken belief that the only way to outperform a human being at a particular task is to copy their thinking process.

What should current and future white-collar workers do in response to these changes? Very simply, they face the same two sets of options that all workers now face. The first strategy is to compete with the machines. This means that they ought to favor work that draws on faculties that, as yet, machines struggle to rival—even when they act in different ways. For instance, jobs that depend heavily on having strong interpersonal skills and an ability to think creatively ought to be favored over those that rely upon learning large well-defined bodies of knowledge and applying them in fairly routine ways. An aspiring accountant, for example, should aim to work in tax planning rather than tax compliance. The second strategy is not to compete with the machines, but instead to build them—to learn the skills and capabilities required of a software developer or a systems engineer.

Policymakers should try to support both these strategies. It is important to note that this may lead to policy prescriptions quite unlike those that seemed appropriate in the second half of the 20th century. Then, as the skill premium rose, it seemed appropriate to focus on how to upskill workers, and move them into white-collar work—supporting formal college and university education appeared to be an appropriate intervention. But whether this will continue is not clear. Many of the tasks and activities that remain difficult to automate are those that are core to low-skilled work like nursing and caring, for instance. And many of the skills and capabilities that are likely to be important in the future are not those that many of our traditional educational institutions, at present, are capable of providing.

NOTES

[1] The statistics mentioned in this article can be found in Susskind and Susskind (2015).

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ANALYSIS

Intelli

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gent automation

Just when we thought that we had all the answers,
suddenly all the questions changed.

Mario Benedetti

UNTIL RECENTLY, MACHINES WERE USED TO AUTOMATE ACTIVITIES IN SECTORS WHERE JOBS ENTAILED INTENSE PHYSICAL ACTIVITY OR LIMITED TRAINING. HOWEVER, THE AUTOMATION OF WORK IS ALREADY AFFECTING MORE SKILLED INDIVIDUALS, INCLUDING THOSE WITH UNIVERSITY EDUCATIONS. LIKE NEVER BEFORE, WE ARE WITNESSING THE CONSTANT CREATION, TRANSFORMATION, AND DESTRUCTION OF JOBS. THIS TEXT ANALYZES HOW WE CAN TAKE ON THAT CHALLENGE AND SUGGESTS CHANGES TO PRODUCTION TECHNIQUES AND THE DISTRIBUTION OF THE BENEFITS OF INNOVATION.

With just a handful of exceptions, almost all the studies to date on the impact of intelligent automation on employment focus on very developed countries, particularly the US. The penetration and impact of intelligent automation is and will be greater in these countries, at least in the short and medium term. But how is automation expected to impact Latin America and the Caribbean (LAC)?

In LAC, there are more than 163 million young people between the ages of 15 and 29, who account for approximately one-quarter of the region's population, and it is estimated that this figure will peak in 2020 (OECD/ECLAC/CAF, 2016). There is, therefore, a very clear window of demographic opportunity to be taken advantage of, but current circumstances are not ideal. Although one in every three people in the region currently belongs to the middle class, nearly two out of every three young people in the region live in poor or at-risk homes.

One-fifth of the young people who live in LAC are informally employed; another fifth are not in education, employment; or training, and only one in four are in education. Indeed, one-third have not finished high school and are not currently going to school. The greatest challenge is the transition from the education system to the labor market: many young people go from school to nothing or to the informal economy.

YOUNG LATINOS

The Telefónica Global Millennial Survey shows that the digital economy has a major presence in the lives of Latino millennials. These young people are undoubtedly better educated than older generations, handle new technologies and the digital environment better, are more adaptable to social changes, and rapidly develop new skills. However, being a user is not the same as being a developer of content, services, and products or an information and communication technologies (ICT) entrepreneur. We need to be aware of this, or Mario Benedetti's prediction may come true: "Just when we thought that we had all the answers, suddenly all the questions changed."

The McKinsey Global Institute (Manyika, Chui, and Miremadi, 2017)[1] has analyzed the percentage of time spent on potentially automatable activities, based on the knowledge and technology available today. The study was carried out in 54 countries and covered 78% of the total labor market. It found that 53% of labor time is spent on automatable tasks in Colombia and Peru, while this figure is 52% in Mexico, 50% in Brazil, 49% in Chile, and 48% in Argentina and Spain. The data for other countries also puts this figure at around 50%. These are averages, considering all sectors of the economy. If we zoom in on specific sectors, we will obviously find notable differences from one to another. For example, in the Mexican manufacturing sector, the percentage of potentially automatable labor time is estimated to be 64%, which would affect 4.9 of the 7.7 million people employed in the sector, while this figure is 34% in the financial service sector and 29% among scientific and technical professional service providers.

A large part of the answer to these new questions will be about education and societies' capacity to innovate. The rate of enrolment in higher education in Latin America went from 22% in 2000 to 43% in 2012. However, this increase was not the same in every

20%

OF YOUNG LATIN AMERICANS ARE NOT IN EMPLOYMENT, EDUCATION, OR TRAINING

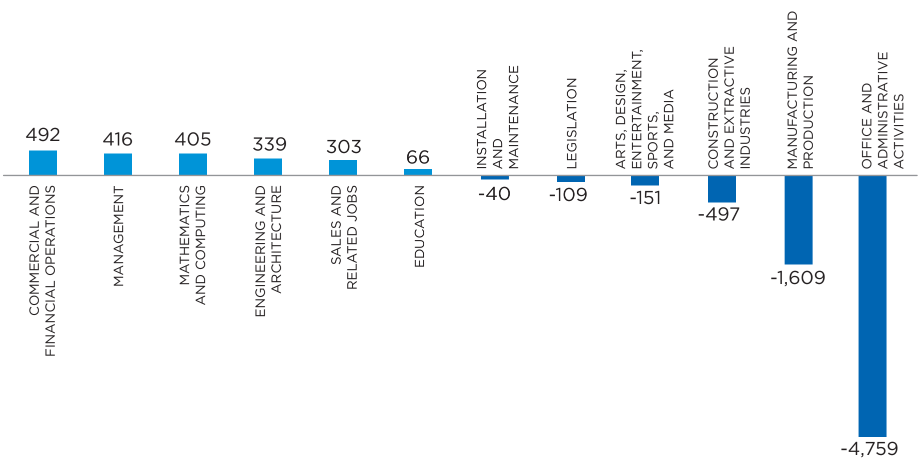
country and it was not reflected in the quality of education. Nor was there an increase in investment that was proportional to this change. Furthermore, Latin America is one of the regions in the world in which education is most out of step with companies' demands. For all of these reasons, there is a need to improve the higher education system, regulate how the quality of educational institutions is measured and certified, reduce dropout rates, which are high, increase the coverage of (public) education options, and develop alternatives to nonuniversity higher education, while balancing out the gender distribution of different fields of study and better connecting the higher education system to the production system.

A World Bank study (Lederman *et al.*, 2014) shows that Latin America is a region with many entrepreneurs but little innovation. There are significant, growing differences in innovation levels between Latin America and other comparable parts of the world. This is true for R&D and patents, but also for innovation in products, services, and processes, even among exporting firms and Multilatinas. One important aspect of entrepreneurship is related to subsistence activities. Some entrepreneurship indicators in countries in the region give a false idea that the situation is very encouraging, particularly among young people. However, the fact is that this generally is not innovative entrepreneurship. Highly innovative entrepreneurship requires much more than just entrepreneurial culture and the will to become an entrepreneur. It also needs financing, specific skills, market access and internationalization, contacts, and regulation, all of which are insufficiently developed in the region, in addition to greater investment in R&D and better transfers of the results from this.

MULTILATINAS

The World Bank study mentioned above (Lederman et al., 2014) reveals certain weaknesses in the profiles of Latin American companies. Many firms get off to a rather scrawny start. They begin with fewer employees than firms do in other regions with similar levels of development and this generally does not change throughout their life spans. Different policies support the creation of businesses and small businesses, but not the process of scaling these up. More and more people are warning of this situation, most notably Daniel Isenberg (2016), a global expert on entrepreneurial ecosystems. In any case, low job creation rates also affect the largest companies in the region. Multinationals that operate in Latin America invest less in innovation than in the other areas of the world where they operate. A single piece of data is highly revealing: US multinationals invest five times more on R&D in Asia than in Latin America. Multilatinas are

FIGURE 1
ESTIMATED NET VARIATION IN EMPLOYMENT 2015–2020 (IN THOUSANDS)



Note: the estimation includes the Association of Southeast Asian Nations, Australia, Brazil, China, Cooperation Council for the Arab States of the Gulf, France, Germany, India, Italy, Japan, Mexico, South Africa, the United Kingdom, the United States, and Turkey.
Source: World Economic Forum (2016).

no exception to this rule. On average, they engage in less industrial protection activity than multinationals, they incorporate less third-party technology, and invest less in R&D. Two possible causes of this, according to the World Bank study, are a certain lack of competition, so there is less incentive to invest in innovation, and a lack of highly skilled human capital.

Research in LAC is mainly concentrated at universities. Indeed, these produce approximately 80% of the region's scientific publications and account for a significant number of patent applications. Some 50% of the region's researchers work at universities, which spend about a third of LAC's R&D budget. They are also almost exclusively responsible for training highly skilled human capital. This was revealed by the first study of how university systems in 21 Latin American countries contribute to the productive fabric (Barro, 2015), which also gave a bleak description of the shortcomings in the transfer of R&D results to this fabric.

53%

OF LABOR TIME IS SPENT ON AUTOMATABLE TASKS

INTELLIGENT MACHINES

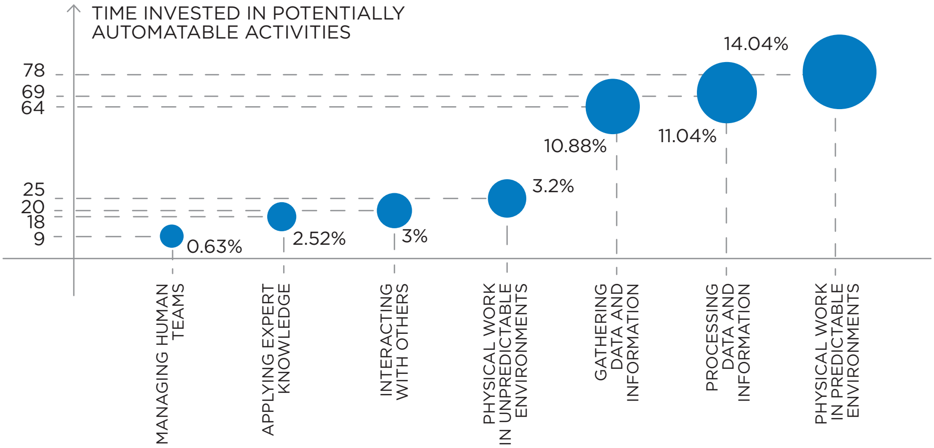
When we speak of the automation of employment, we are not referring to the use of tools, be they physical or otherwise, that help us to perform our work better, but rather to that work being entirely performed by machines. For example, there is a huge difference between navigation systems that show us the best route while we're driving and fully autonomous cars, which are already being tested in real traffic conditions.

Intelligent automation is the use of machines or systems that can emulate or even surpass human ability to carry out complex tasks requiring intelligence. The boom in intelligent automation stems from the major advances taking place in ICTs in general and robotics and artificial intelligence (AI) in particular.[2]

The Japanese insurance company Fukoku Mutual Life Insurance recently replaced tens of employees with a computerized system for evaluating payouts to policy-holders (McCurry, January 5, 2017). This system is based on the Watson Explorer,[3] IBM software that has been evolving since it was used in 2011 to defeat two of the best (human) players in the history of the game Jeopardy. This is just one of many such examples.

An interesting report from the World Economic Forum (2016)[4] on the future of work estimates that 5.1 million jobs will be lost between 2015 and 2020 in the countries that were analyzed. These are net job numbers, so even though it is thought that 2 million new jobs will be created, mainly in the financial and administration sectors and in engineering, particularly computing, the total number of jobs that would be destroyed would be 7 million, two-thirds of which would entail routine office and administrative tasks. Workers in the manufacturing and production sector will also be par-

FIGURE 2
POTENTIAL FOR INTELLIGENT AUTOMATION



Note: The y-axis shows the percentage of time invested in potentially automatable activities for each of the different labor activities (x-axis). The size of each circle indicates what percentage of the more than 800 occupations analyzed are automatable, grouped into the different activities included on the x-axis (in total more than 45%).
Source: Chui, Manyika, and Miremadi (2016).

ticularly affected, but their probability of re-employment is higher. Another study that is often cited is that of Frey and Osborne (2013). These researchers have analyzed how susceptible more than 700 jobs or occupations that are currently being carried out by humans are to automation. According to the authors, approximately 47% of current jobs in the US are at risk (in as little as a decade or two). The most endangered are worse-paid jobs that do not require special training. An OECD study (Arntz, Gregory, and Zierahn, 2016) estimates that around 9% of jobs will be automated in OECD countries and that the ultimate balance of lost jobs might be even lower. According to the study, there are basically three reasons for this: first, the slow spread of automation technologies for economic, legal, and social reasons; second, some of the workers that are replaced by automation can carry out other jobs; and new jobs will be created, many of which will derive from new technologies and productivity increases.

A McKinsey & Company study for the US labor market (Chui, Manyika, and Miremadi, 2016) analyzed 12,000 activities carried out in 800 occupations, quantifying the time that employees invest in them and the technological viability of automating them. Current scientific-technological capacities (solutions that are commercially available or being researched) show that 45% of activities that are currently part of paid work could be automated (figure 2) and that at least 30% of the activities carried out in approximately 60% of all occupations are now automatable. According to the authors, around half the labor time in the financial and insurance sector is spent on obtaining and processing data and information, two activities with high automation potential. Sectors such as manufacturing, food processing, hospitality, or commerce all have highly automatable jobs. It is thought that around 78% of the activities carried out in these jobs are highly specific physical jobs that are extremely suited to automation, such as those of welders, assembly line operators, packers, or food processors. In contrast, only 25% of less systematic physical activities in less predictable environments are automatable, such as large-scale animal farming or forestry. This figure is even lower in other areas, such as education or the cultural and creative industries.

Although these and many other studies vary greatly in terms of the focus of their analysis, both the methodology used and the results they arrive at underline the enormous impact of intelligent automation on employment.

25%

OF PHYSICAL TASKS IN UNPREDICTABLE ENVIRONMENTS COULD BE AUTOMATED

JOB CREATION

Some researchers and experts argue that, as happened on other occasions when jobs were eliminated by technological progress, many more jobs will be created, generally because of these selfsame technological advances. Although this is possible, we currently do not have sufficient evidence to support the claim. The first reason for this is the difficulty of anticipating these possible future jobs—saying that most of today's children will do jobs that do not yet exist or talking of the job creation potential of new technologies, such as drone pilots, to take just one example, are little more than unsubstantiated flights of fancy. The second reason is that current circumstances are very different to those of the past, and so is the future that they point to. In particular, as I commented above, many activities that are already being automated are far from being low-skilled.

Making predictions is a complex task when the present moves so fast and the future seems so hazy, but a US government report (Lee, 2016) points to four categories of jobs that may be created as a result of intelligent automation:

Jobs that are directly linked to the intelligent automation process itself. Big data or machine learning experts are good examples of these.

Jobs entailing tasks that are amplified by intelligent automation, such as professionals whose decision-making processes are assisted by expert systems in a range of fields.

Jobs overseeing intelligent systems by monitoring or maintaining them, for example.

Jobs created by the paradigm shift, such as those that are related to legislative or safety issues that derive from the new operating conditions for intelligent machines, as will be the case with self-driving cars.

What is unclear is whether all these jobs and others that may derive from the introduction of intelligent technologies and the resulting progress and increased productivity will make up for the human jobs that these technologies will render unnecessary.

THE ETERNAL PROBLEM OF MEASUREMENT

The benchmark indicator for measuring economic growth is widely assumed to be output per inhabitant or GDP per capita. However, job productivity (GDP per employee) will gradually decrease as the main source of economic growth (GDP per capita). It will be replaced by two new factors: productivity per employment unit and employment automation rate. An employment unit could be performed by a human worker or a machine that carries out work that would otherwise be performed by humans.

This can be expressed through the following equation:

$$\frac{\text{GDP}}{\text{Population}} = \frac{\text{GDP}}{\text{Employment unit}} \times \frac{\text{Employment unit}}{\text{Employees}} \times \frac{\text{Employees}}{\text{Population}}$$

The first term is the classic measure of GDP per capita. The terms after the equals sign are productivity per employment unit, the rate of employment automation, and the rate of human employment (over the total population).

GDP per capita can therefore only be increased by increasing any of the other three factors after the equals sign. Bearing in mind that the rate of employment over the total population is clearly limited (by demographics, regulations, and so on), GDP per capita can be increased by raising the rate of job automation or the productivity per unit. This supposes greater automation of the work being done, which in turn implies more skilled labor, leading to greater yields. If this skilled labor was being carried out by artificial employment units (machines), it would require them to be more intelligent. Generally speaking, the more intelligent the machine, the higher productivity levels are.

If we apply this equation to the planet as a whole, the intelligent automation of employment is the best way of increasing GDP per capita and achieving economic growth. However, outcomes could be very disparate at the local level. For example, the situation in one specific activity sector or geographic environment may influence others significantly. The increase in employment automation rates and productivity per employment unit in a country may compensate for and even surpass the destruction of human employment there. But if the work that is now automated was previously carried out by people in another country, this compensation may not take place. In fact, large companies are already using automation to bring tasks that they had been outsourcing abroad back to their home countries. The less-developed regions of the world will be especially vulnerable to such changes.

1.4%

IS THE MAXIMUM ANNUAL PRODUCTIVITY INCREASE RATE EXPECTED UP TO 2065

THE SECTORS AT STAKE

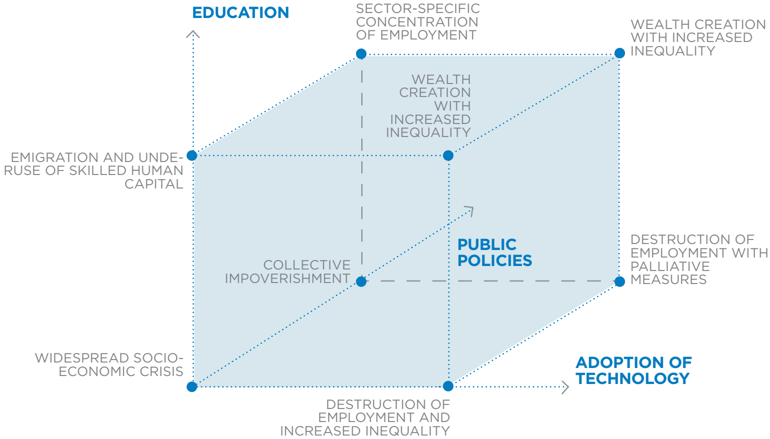
The issue of intelligent automation is so complex and will make such a large impact that, one way or another, we will all have to form an opinion on it and react to it. The above-mentioned US government report (Lee, 2016) clearly suggests that policymakers should be preparing themselves and us for five primary effects of an economy based on intelligent automation:

- "Positive contributions to aggregate productivity growth;
- Changes in the skills demanded by the job market [...];
- Uneven distribution of impact, across sectors, wage levels, education levels, job types, and locations;
- Churning of the job market are some jobs disappear while others are created; and
- The loss of jobs for some workers in the short run, and possibly longer depending on policy responses."

The report advocates for strategies to educate and prepare new workers for entry into the labor market, buffer the impact on those who lose their jobs, and combat inequality. Whether or not intelligent automation brings about unemployment and inequality in the long run is not set in stone—what happens will depend largely on governments and their policies. This article does not question the value of AI and intelligent automation in general or its potential economic benefits—quite the contrary. However, it does argue that although 19th-century technology served to increase the productivity of less skilled workers and, thus, their labor market value, in recent years technologies have increased the productivity and value of more highly skilled workers, thus increasing inequality. The workers that benefit most from the new situation will be those with specific skills in abstract reasoning, creativity, and decision-making.

Just over half the human resource supervisors interviewed by the World Economic Forum (2016) believe that their organization is well prepared for what is on the horizon. That's the optimistic outlook. The pessimistic view is that nearly half of these supervisors believe that they are not ready, particularly due to "a lack of understanding of the disruptive changes ahead, resource constraints and short-term profitability pressures, and a lack of alignment between workforce strategies and firms' innovation strategies" (World Economic Forum, 2016), to cite the main barriers. Furthermore, 65% of organizations expressed their intention to invest in reskilling their current employees as part of their strategy for the future, with supporting mobility and job rotation coming a distant second (39%), followed by collaboration with educational insti-

FIGURE 3
THE DIGITAL ECONOMY CUBE



Note: The further along an axis point is from the origin, the better developed the factor that it represents is. The vertices represent situations that are particularly high-impact due to their socio-economic consequences.
Source: Compiled by the author.

tutions (25%), targeting female talent (25%), and attracting foreign talent (22%).

There is no doubt that large firms will play a decisive part in this process: not just by deciding to increase automation or not but through the way that they do so, particularly in terms of human resources. Although public policies will play the greatest role in amplifying or mitigating the negative effects that intelligent automation could bring, employers must commit to seeking a responsible return on this, one that focuses not only on economic gain but is also sensitive to the needs of workers and people in general.

While it is true that we cannot demand that citizens in general (students, researchers, and professionals from different fields) take on collective responsibilities, we should take advantage of the opportunity, and indeed the need, to obtain (and demand) a good education and continue to engage in training throughout our lives. At the same time, researchers and developers of the technologies that underlie intelligent automation must commit to thinking ethically about machines that serve humanity.

THE DIGITIZATION OF THE SYSTEM

The impact of intelligent automation on a given environment—a specific country, for example—will be particularly conditioned by the education of the population, particularly the potential working population; the adoption of technologies that favor the digital economy; and, specifically, the automation of different sectors of activity; and the public policies established by governments not just in relation to regulatory matters and labor legislation but also in terms of taxation and fiscal issues, social benefits, investments, and so on. How well or how badly we act in relation to each of these three core areas will give rise to very different socioeconomic outcomes. Figure 3 shows eight concrete scenarios which correspond to the corners of a cube defined in terms of how each of the three aforementioned areas is handled: education, public policies, and technology adoption.

The studies that analyze the potential job losses that may come with intelligent automation agree on several points. First, that this will be greater among less skilled workers. Second, that the knowledge, skills, and abilities that are required in many occupations and activities today will not be the same as will be required in a few short years. Third, more than ever, lifelong learning will be essential to prevent our labor life from being rapidly overshadowed by intelligent automation.

According to the World Economic Forum (2016), we need to seriously rethink current education systems, something that is primarily the responsibility of governments. We cannot expect to train 21st-century professionals with 20th-century teaching practices in 19th-century classrooms.

Many analysts indicate that we need to improve science, technology, mathematics, and engineering (STEM) education among young people if we want to take on intelligent automation and provide guarantees in relation to it, in terms of both effectively incorporating it and mitigating its effects on unemployment. Of course, there is no denying the importance of such training among those who will be professionals in the very near future. However, there is another sort of STEM that we must not overlook. This encompasses social skills, such as empathy, teamwork, and intercultural relations; technical skills, in relation to ICTs, directing and decision-making, and oral and written expression, among other factors; executive skills, such as leadership, entrepreneurship, and self-management; and mental skills, including persistence, resilience, self-knowledge, and so on. These types of skills will be increasingly important in carrying out activities that machines will take much longer to learn to do. Even those who are well qualified in the first set of STEM skills will need the second set to do their job well.

If we analyze the digital economy cube (figure 3) in more detail, particularly its eight corners, we find that if the action taken on any of the three fronts is nonexistent or insufficient, eventually there will be a widespread socioeconomic crisis (1). Only a good education system can guarantee well-trained, competent human capital, but if the other axes are not developed, such capital will tend to be underemployed or will seek work that is appropriate to its skills in other places or countries (2). If there is also a rapid assimilation of production technology, highly qualified employment and wealth may be created, but at the cost of an increase in socioeconomic inequality (3). If education and public policies are developed favorably but there is no appropriate adoption of technological resources to create a competitive economy, the only sectors to develop will be the less automatable ones and they will only do so temporarily (4). If technological breakthroughs are the only factor guiding the economy, in the absence of suitable training for professionals and public policies on regulatory matters, taxation, and social support, there will be a major loss of employment and an increase in inequality (5).

In any case, this outcome is highly improbable, given that it would hardly attract the investment that intelligent automation requires. Having good public policies that coincide with the appropriate spread and use of technology will not prevent large-scale job destruction, but there is at least a chance that palliative measures for unemployment and social inequality could be put in place (6). If this is not the case, there will be a widespread increase in poverty (7). Finally, the virtuous corner is the one where the three axes develop favorably and harmoniously (8). This is something that all countries should aspire to, although the road there will generally not be direct or easy. Of course, this analysis is in some senses superficial and, in any case, the corners described here are merely a handful of possible outcomes in the face of infinite possibilities. Regardless, it may be useful to focus on the most relevant issues and the variety of situations that they may lead to depending on how they are handled.

THE MIDDLE-INCOME TRAP

Intelligent automation requires a change in the economic model and the division of labor and the benefits of labor, regardless of whether this is carried out by people or machines. We need a new economy, and it should be states, not markets, that establish certain rules. If they do not, wealth will be increasingly concentrated in the hands of the few, particularly those that are able to design and use the technologies that will allow work to be progressively automated. Less-skilled workers will lose their jobs and will find it very difficult to reinvent themselves. More-skilled workers will often have to do perform jobs that are below their theoretical skill level.

In this context, salaries are likely to come down even if firms' profitability increases due to the oversupply of human labor, and wealth will be concentrated among the owners of financial and industrial capital. The presence of the state is fundamental if we are to avoid worst-case scenarios. Appropriate public policies need to be planned, including in education. For example, Lee (2016) believes that appropriate measures would include increases to wages, competition, and worker bargaining power (labor unions are yet to take on a relevant role in this matter). Other policies would improve the social safety net, favor lifelong learning and the re-inclusion of workers in the labor market, and adjust tax policies to this new economic and social reality. There is probably no one standout measure—all are needed at the same time.

The McKinsey Global Institute estimates that the increase in global productivity up to 2065 will be between 0.8% and 1.4% per year, based on the growing automation of economic activities. This figure is well above the 0.3% increase that the steam engine brought between 1850 and 1910, the 0.4% rise that came between 1993 and 2007 with the emergence of industrial robotization, or even the 0.6% increment due to ICTs between 1995 and 2005.

The so-called middle-income trap could lead to stagnating productivity in Latin America, but there is a worse trap, which is closing the doors to automation altogether. Failing to adopt intelligent automation would lead to a serious loss in competitiveness in the region. Imagining that preventing these technologies from making inroads into the labor market is a way of avoiding the potential problems they may bring is like closing your eyes to avoid being hit by a stampeding bull.

The spread of intelligent automation will not happen overnight, but it will happen. The different rates at which it is adopted from one country to the next and within each country will lead to huge inequality. This process will reduce the competitiveness of less-developed countries that are hoping to continue developing based only on the capacity of human labor. It will also endanger employment within companies seeking to compete with other highly automated firms by reducing employee wages.

NOTES

[1] The main data from Manyika et al. (2017), *A Future That Works: Automation, Employment, and Productivity*, can be accessed through a useful graphic interface at http://public.tableau.com.

[2] A study by the US government (Lee, 2016) which I will return to later uses the term "AI-driven technologies" to describe intelligent machines that allow work to be intelligently automated.

[3] Watson Explorer is a cognitive search and content analysis platform that uses vast quantities of information. It seeks and analyzes structured and unstructured information contained in both internal, external and public domain repositories and finds patterns and trends to support its decision-making processes. https://www.ibm.com/watson/.

[4] This study is based on an extensive survey of human resource managers and other high-ranking executives and experts at 371 of the world's largest employers, who collectively represent more than 13 million employees in nine industrial sectors from 15 developed or emerging economies or global economic areas.

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INTERVIEW

“We need to **guarantee social security benefits** for freelancers”

Alan Krueger
Princeton University

ACCLAIMED AS ONE OF THE GREATEST GLOBAL EXPERTS ON THE LABOR MARKET, PRINCETON PROFESSOR ALAN KRUEGER BELIEVES THAT THE LONG-TERM RESULTS OF AUTOMATION WILL BE POSITIVE. HOWEVER, HE WARNS OF THE NEED FOR NATIONAL TAXATION SCHEMES THAT DO NOT CREATIVE GREATER INCENTIVES FOR INVESTMENT IN CAPITAL THAN IN LABOR, AND HE POINTS TO THE NEED TO EXPAND SOCIAL BENEFIT COVERAGE TO INCLUDE PART-TIME WORKERS.

How do disruptive technologies affect employment?

By their nature, disruptive technologies destroy jobs and businesses in one area and create them in another. That is the nature of creative destruction. The difficulty arises when the new jobs being created require very different, and more advanced, skills than the jobs that are being destroyed. This creates serious challenges—and, too often, hardships—for workers who are displaced. In recent work that I've done, I found that half of net job growth in the U.S. since 1999 has occurred in new occupations. This shows the importance of having flexibility in the economy and supporting innovation, and the challenge of helping people make the transition to new and emerging jobs.

Do you think digital transformation will create more jobs than it destroys?

I think that digital transformation will improve the quality of services and create new services. For example, the ability to use adaptive learning techniques can improve access to education and the quality of education in some fields. Likewise, artificial intelligence and expert systems have great potential to improve medical diagnoses.

It is possible that net jobs may be reduced or increased. I am not sure that is possible to predict right now. But eventually this technology should lead to productivity gains and higher living standards. I am very concerned about the distribution of jobs across worker skill types, in addition to the sheer number of jobs. Historically, we have been able to create more jobs for a growing population despite technological change. But the technological change has caused inequality to rise and eroded the middle class in many countries.

What do you think of the collaborative economy? How does it affect the generation of employment? Does it call for new forms of regulation?

I think that the rise of digital platform jobs provides an opportunity and a challenge. Seth Harris and I have made an extensive policy proposal in this area to extend much of the social compact to gig economy workers, and, in particular, the parts that make sense for this emerging segment of the workforce. Our proposal includes guaranteeing freedom to unionize and engage in collective bargaining, access to civil rights and social protection, and tax contribution mechanisms for both workers and employers.

AFTER EARNING HIS PHD AT HARVARD UNIVERSITY, ALAN KRUEGER BEGAN A BRILLIANT ACADEMIC CAREER AT PRINCETON UNIVERSITY, WHERE HE HAS TAUGHT SINCE 1992. HE WAS CHIEF ECONOMIST AT THE UNITED STATES DEPARTMENT OF LABOR AND CHAIRMAN OF THE COUNCIL OF ECONOMIC ADVISERS TO FORMER PRESIDENT BARACK OBAMA. HIS MAIN PUBLICATIONS INCLUDE:

"Measuring Labor's Share." *American Economic Review* 89 (2). 1999.

"Time Use, Emotional Well-being, and Unemployment: Evidence from Longitudinal Data." *American Economic Review* 102 (3). 2012.

"Disruptive Change in the Taxi Business: The Case of Uber." *American Economic Review* 106 (5). 2016.

Do you think that the extended practice of freelance may create a social security problem in the future?

I think we need to "level up," meaning make it possible for freelance workers to obtain the benefits and protections of traditional employees, while maintaining the flexibility that freelancing provides.

Do you consider that a tax on robots, as some European countries propose, would be a good idea?

It is an intriguing idea. My initial reaction is that our tax code should not favor capital investment over human capital investment. I don't know if I would single out robots over other forms of capital in applying this principle. Currently, I think we need to look hard at the tax code in many countries to ensure that capital investment is not given favored treatment over workers.

Is basic universal income possible? Could it be the answer to automation?

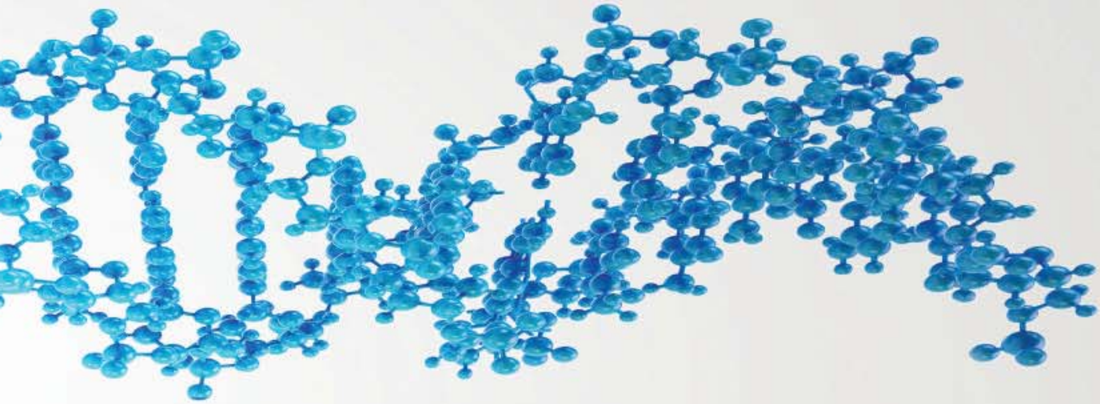
There is a great deal of research going on in this area, and we will know more in the next few years. My initial reaction is that universal basic income makes sense for some countries, and is potentially a very efficient and fair way for wealthy countries, philanthropic institutions, and individuals to transfer money to low-income, impoverished people in developing countries. I am less convinced that it makes sense for the US, where we tend to tie income support to work, or to categories of individuals who are incapable of working and earning a decent living.

How should we educate the next generations for the future of the labor market?

For a long time, I have felt that we should seek to accelerate the use of technology in education. This technology also has great potential to help older workers with continuing education and job-related training. It makes me optimistic about the future.

ANALYSIS

Irmgard Nübler
International Labour Organization



Transforming production

Opportunities for middle-income countries

Machines have calculations; humans have understanding.
Machines have objectivity; we have passion.

Gary Kasparov

THE FOCUS OF THIS ARTICLE IS INDUSTRIAL ROBOTS AND THEIR EFFECT ON JOBS AND EMPLOYMENT IN MANUFACTURING. IT REVIEWS RECENT DYNAMICS IN THE MANUFACTURING INDUSTRY AND DESCRIBES THE OPPORTUNITIES THAT NEW TECHNOLOGIES OFFER DEVELOPING COUNTRIES.

Since the Industrial Revolution 250 years ago, mechanization and automation have become one of the major long-term trends in technological change. Industrialization has shifted production from workshops to factories, and from customized products to standardized products, which contributed to the automation of human tasks. Markets' quests for higher productivity, precision, and quality, as well as political and social demand for labor and environmental standards, induced the search for new technologies and innovations to develop increasingly sophisticated machines and production processes. Robots and artificial intelligence are the most recent forms of innovations along the long-term trend toward automation.

The International Federation of Robotics (2015) defines an industrial robot as "an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications." Acemolgu and Restrepo (2017) describe robots as fully autonomous machines "that can be programmed to perform several manual tasks such as welding, painting, assembling, handling materials, or packaging."

More recently, a new generation of robots is emerging that are characterized by increasing complexity, mobility, diversity, connectivity, and self-learning. They have the power to fundamentally change the future of work, both in terms of quantity and the nature of jobs. Some believe that technological innovations and the rise of robots will destroy jobs on a massive scale, forecasting a jobless future. Others are confident that forces will be mobilized to create new jobs and that a golden age of quality job creation may even arise. This optimism is supported by historical experience, which demonstrates that initial phases of job destruction were eventually followed by strong job creation (Mokyr, Vickers, and Ziebarth, 2015; Pérez, 2016). One of the central issues in developed countries is, then, whether the current wave of robotization, after a phase of job destruction, will once more generate a sustained process of job creation. Another important question is how policies can support this process to meet the aspirations of societies.

While the current debate on robotization and jobs is mainly focusing on developed countries, which are the main drivers of R&D and production of these new technologies, robots will also affect the future of work in developing and emerging countries. Developing economies are integrated into international markets and production systems and, therefore, robot technologies may affect developing countries by either creating new opportunities for industrial development or new risks of losing manufacturing activities. Hence, in developing countries, the issue is whether robot technologies will limit or expand the potential for catching up in productivity and jobs.

200+

THE NUMBER OF ROBOTS PER 10,000 WORKERS IN KOREA, JAPAN, GERMANY, AND SWEDEN

DISTRIBUTION BETWEEN COUNTRIES

Most robots are installed in developed countries (80%) and are highly concentrated in manufacturing, as service-sector robots have emerged only recently. In 2015, the global operational stock of industrial robots in the 50 countries for which data is available was 1,631,650, of which manufacturing accounted for 1,393,646 robots (IFR, 2016). This implies that both income level and economic structure reflect a country's ability to deploy robots.

Figure 1 shows significant differences across countries in terms of robot density, measured as the number of industrial robots per 100 manufacturing workers. While figure 1.A shows countries with relatively low robot density in manufacturing (RDm < 0.5), figure 1.B shows data for countries with relatively high density (RDm > 0.5). In 2014, the highest robot density in manufacturing was achieved by Korea followed by Japan, Germany, Sweden, Singapore, Denmark, the United States, and a number of other European countries. Interestingly, in 2014, the East Asian tigers Korea, Singapore, Hong Kong, and Taiwan were among the countries with the highest robot densities.

It is striking to see the differences in RDm between developed and middle-income countries, but also between developing regions. Most developed countries have a robot density close to 1 or above, while developing countries have an RDm well below 0.2, with the exception of Thailand, Malaysia, and China, which achieved an RDm of over 0.2. The countries with an RDm of over 0.2 seem to be those with great potential for catching up, as they have demonstrated innovation capabilities but were not yet able to fully exploit them. Moreover, a look at the so-called BRICS (Brazil, Russia, India, China, and South Africa) shows that they all had low robot density (RDm < 0.1) in 2008. While South Africa achieved some increase in RDm, only China fulfilled the promises and achieved an RDm above 0.2.

Countries also differ significantly in the growth of robot density between 2008 and 2014. As indicated by the numbers above the blue bars in figure 1, the percentage change in robot density was lowest in developed countries. These high-wage countries compete in cutting-edge technologies and the quest for higher productivity has driven high levels of robotization in the past. In Japan, robot density even declined. Interestingly, the Asian tigers have been catching up in RDm with the "old" developed countries, as demonstrated by the relatively high growth rates in RDm between 2008 and 2014.

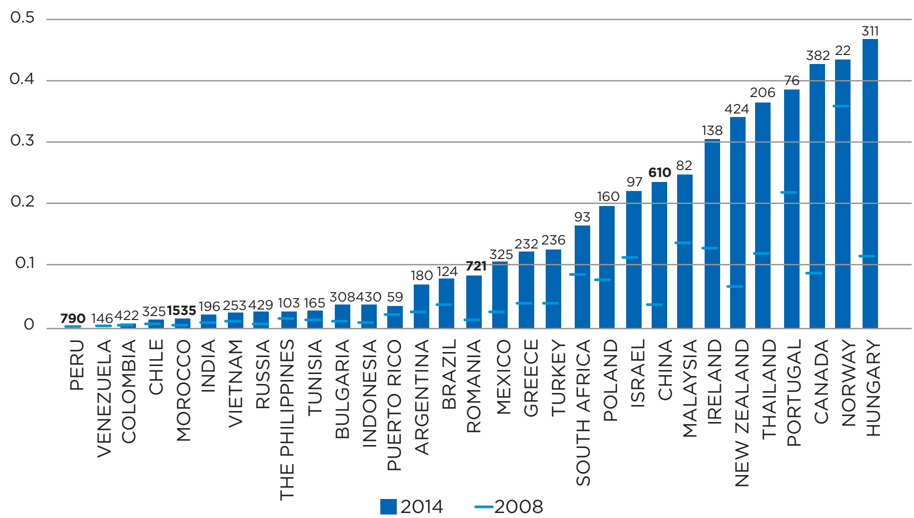
CREATIVE DESTRUCTION

Historical experience shows that technological change is a complex, nonlinear, costly, evolutionary process which triggers a dynamic process of creative destruction. New technological paradigms come in waves that contain different phases and this process destroys jobs in a first phase but also creates new jobs in the following phases. The important insight provided by history is that the consequences of productivity-enhancing but job-destroying technological changes trigger adjustment processes. These create new jobs because they expand output and generate new economic activities, products, and industries (Pérez, 2016).

Early industrial robots were installed in factories in the 1960s. Computer-controlled automation performed routinized, heavy, and dangerous work, and was mainly installed in the automobile, chemical, and basic metal industries.

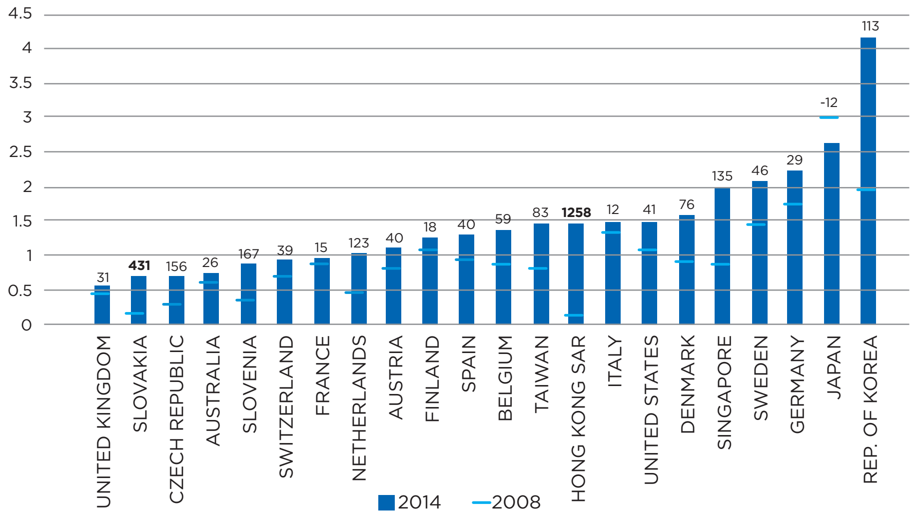
Work processes were standardized, codified, and encoded in algorithms, which were then performed by robotics. In the early 1970s, the introduction of microprocessors and increasing computing power created a new techno-economic paradigm with robots that could also simulate manual nonroutine work and cognitive tasks

FIGURE 1
ROBOT DENSITY ACROSS COUNTRIES IN 2008 AND 2014
A: LOW-DENSITY COUNTRIES



Source: International Federation of Robotics (2016).

ROBOT DENSITY ACROSS COUNTRIES IN 2008 AND 2014
B: HIGH-DENSITY COUNTRIES



Source: International Federation of Robotics (2016).

(Autor, Levy, and Murnane, 2003). The latest generation of robots is mobile, autonomous, and self-learning. They combine multiple new technologies, and the range of functions they can perform is being expanded by the invention of advanced laser, infrared, and ultrasonic sensors, imaging technologies, increasingly complex and optimizing algorithms, as well as exponentially growing data processing capacities.

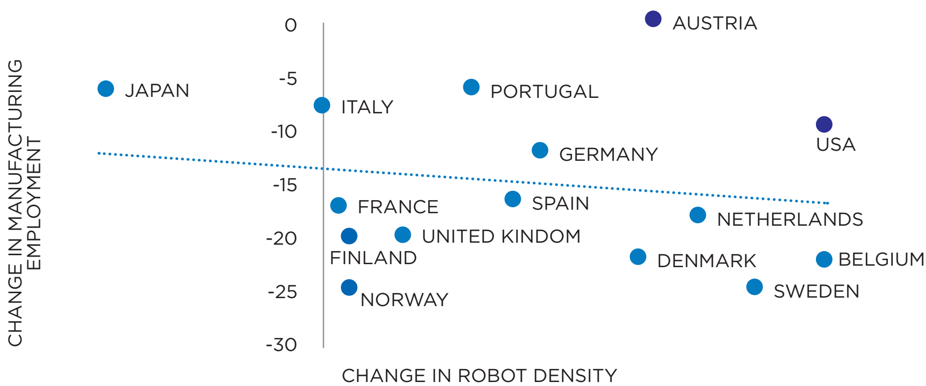
This new generation of robots will continue to destroy jobs, possibly on a large scale. It is hard to know the magnitude of job destruction in the near future because it depends on the technical feasibility of automating jobs, economic factors like prices for robots and wages, entrepreneurs that discover new "exploitable opportunities" to deploy these robots, social desirability, as well as the political and regulatory environment. Some attempts have been made to estimate this. While Frey and Osborne (2013) explored the technical easiness of automatability of occupations and estimated that potentially almost half of total US employment may be at risk, critics argue that jobs vary within occupations, and while some jobs may disappear, others will only change (Autor and Handel, 2013). These studies find significantly lower risks for job losses (Arntz, Gregory, and Zierahn, 2016). Moreover, the new type of robots will complement rather than substitute human tasks. They will collaborate with workers, in large, small, and medium-sized enterprises, including in specialized tasks or niche markets. These collaborative robots ("cobots") work alongside humans, and may even create new jobs when they replace large industrial robots, for example when products are customized. These new trends are observed in car factories in Germany where Mercedes, BMW, and Audi are testing cobots for producing individualized high-end models (Behrwald and Rauwald, 2016).

While the debate on robots is preoccupied with forecasting the scale of job losses, it may be more important to understand how robot technologies impact job creation and the creation of better jobs. Economists discuss a range of effects (see Nübler, 2016 for an overview). Robots may increase productivity, and the scope for job creation is determined by the way this productivity increase is shared between different groups in society. The central point is that jobs are created through output expansion either in existing industries or by creating new products and activities. These effects, however, are not automatic. New jobs can only be created when productivity gains are shared in the form of higher wages and/or falling prices. This increases purchasing power and demand. Another way of sharing productivity gains is to reduce working hours. In combination with higher income, it boosts new industries in leisure-related goods and services in sports, health, recreation, tourism, music etc. At the same time, enterprises need to translate higher productivity and profits into investment.

On the other hand, complementary effects will be triggered in the capital and consumer industries. The robots which displaced workers in user industries create demand for workers

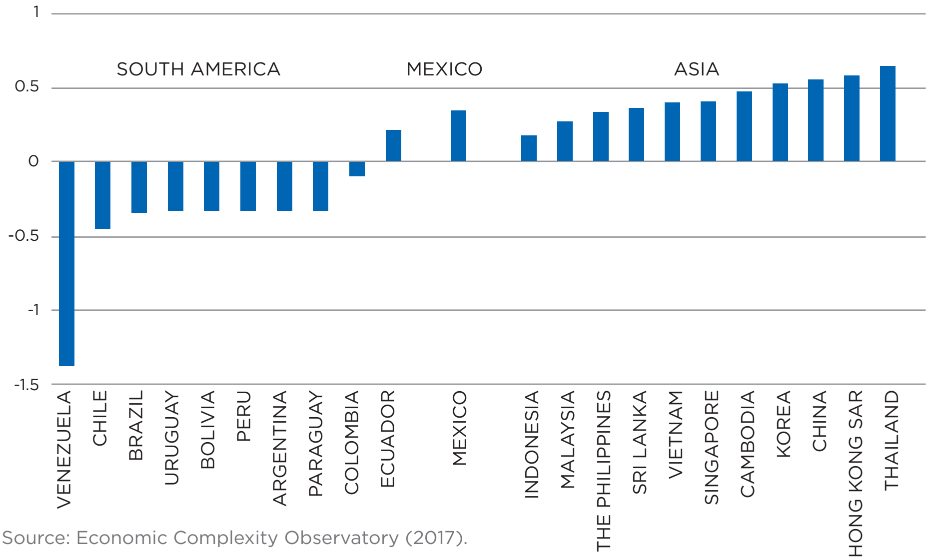
FIGURE 2

CHANGE IN ROBOT DENSITY (IN NUMBER OF ROBOTS PER 10,000 MANUFACTURING WORKERS) AND DECLINE IN MANUFACTURING EMPLOYMENT (AS A SHARE OF TOTAL EMPLOYMENT), IN PERCENTAGE, 2008-2014



Source: Trends Econometric Model database, ILO (November 2016); IFR (2016).

FIGURE 3
CHANGE IN ECONOMIC COMPLEXITY IN LATIN AMERICAN AND ASIAN COUNTRIES, 1998-2008



Source: Economic Complexity Observatory (2017).

in producer industries. The new robots and learning machines need to be developed, designed, built, maintained, and repaired, and they require the development of increasingly complex software and algorithms. Moreover, compensation effects may create jobs. For example, the use of automated teller machines destroyed jobs but banks expanded the number of branches in order to maintain customer relationships which created jobs. Spillover effects from the robot industry may generate new products in other industries. For example, Michelin has integrated sensors into tires and is collecting vast sets of data which allows the establishment of a manufacturing-cum-service business model (Nübler, 2016).

Finally, robot technologies change the nature of jobs, increasing the complexity of task profiles and thus also the skills people need in these new jobs. The "paradox of automation" is that it requires "highly skilled, well-trained, well-practiced people to make systems resilient, acting as the last line of defense against the failures that will inevitably occur" (Baxter et al., 2012). As a consequence, innovative learning ecosystems which will create jobs for teachers, trainers, or coaches. In fact, educationalists, software experts, and engineers will have to develop new teaching and training approaches, for example, based on artificial intelligence.

This raises the question of whether the increase in industrial robot density is reflected in the change in manufacturing net employment. Interestingly, we find no strong statistical relationship between growth in robot density and loss in manufacturing employment, as shown in figure 2. Despite the fact that Austria, the United States, and Germany showed the highest increase in robot density during the post-2008 crisis period, they lost significantly fewer jobs in manufacturing (as a share of total employment) than the UK, Norway, Finland, and France, that is countries with much lower growth in robot density in this period.

These findings show that developed countries not only differ in robotization, but they differ in their capabilities for managing the adjustment processes and generating those changes in economic structures and societies that are essential for entering the phase of job creation. Adjustment processes to create new jobs at a massive scale cannot be achieved by markets alone, as they require transformative changes in consumption, production, and industrial structures. This, in turn, requires societal transformation which creates new social demand and new social capabilities. Hence, while jobs destruction is the direct effect of installing robots, the dynamics of job creation is not so much a technical but a societal and political issue (Nübler, 2016).

MIDDLE-INCOME COUNTRIES

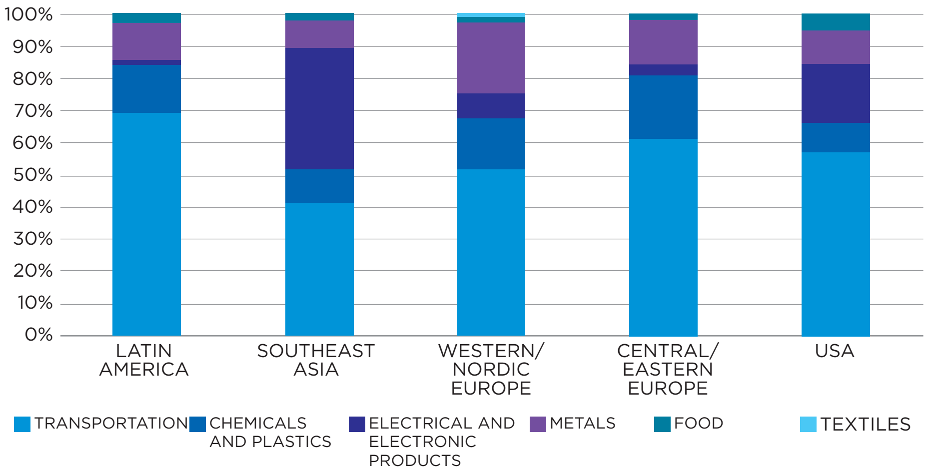
While the debate on the future of jobs is mainly focusing on developed countries, developing economies, and in particular middle-income countries, have the potential to benefit from

TABLE 1
GLOBAL ROBOT INTENSITY BY INDUSTRY

INDUSTRY	ROBOT INTENSITY (NUMBER OF ROBOT PER MILLION HOURS WORKED IN INDUSTRY), 1993	CHANGE IN ROBOT INTENSITY, 1993–2007
TRANSPORTATION EQUIPMENT	5.36	8.07
METALS	2.37	1.67
CHEMICALS	1.16	3.33
ELECTRONICS	0.95	1.32
WOOD PRODUCTS	0.77	0.84
FOOD PRODUCTS	0.34	1.21
TEXTILES	0.12	0.30
PAPER	0.06	0.14

Source: Graetz and Michaels (2015).

FIGURE 4
DISTRIBUTION OF STOCK OF ROBOTS ACROSS INDUSTRIES, BY REGIONS, 2014.

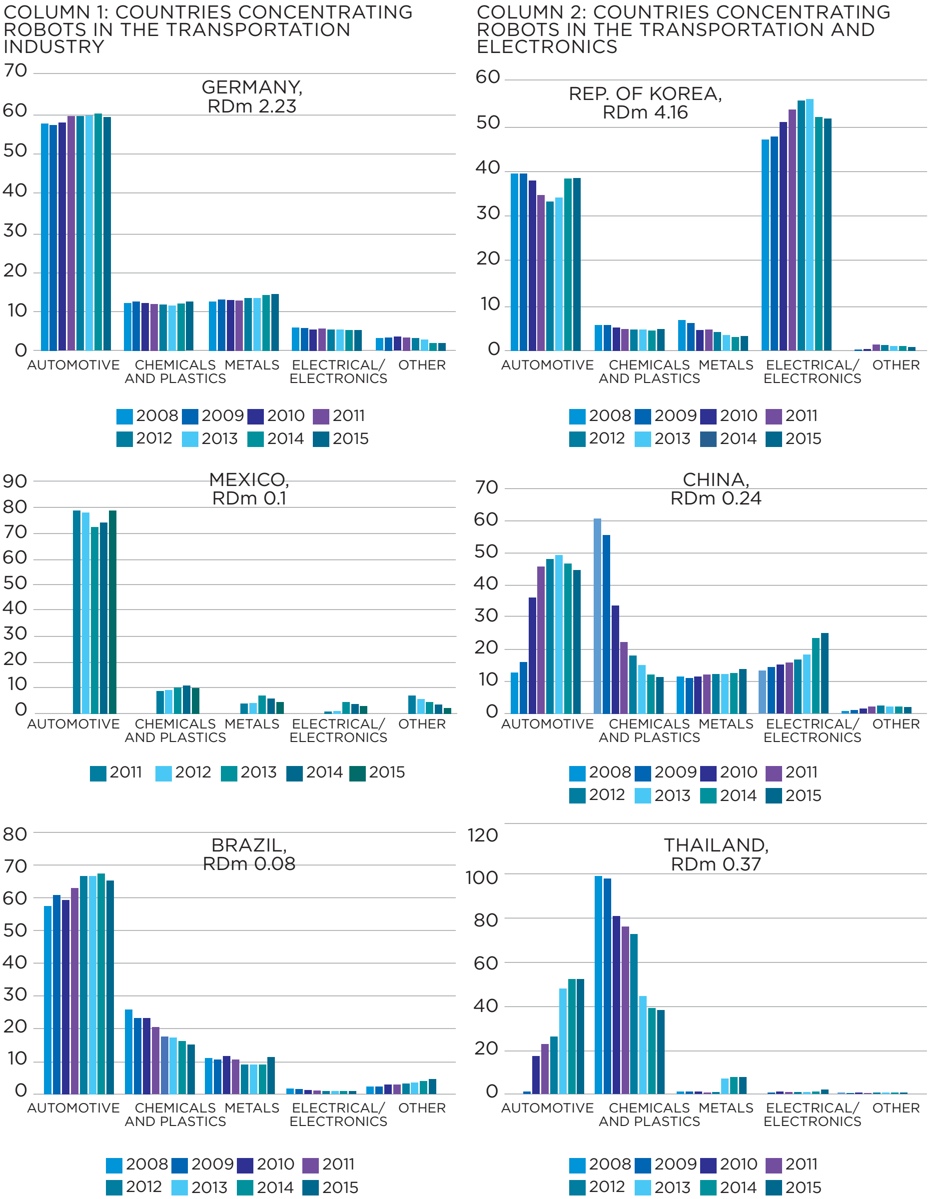


Source: International Federation of Robotics (2016).

newly emerging robot technologies. Development economics highlights structural transformation, diversification and increasing complexity of products as central drivers of a rapid and sustained process of economic development. Evidence from successful catching-up countries, in particular the Asian tigers, and insights provided by evolutionary and structural economists, suggest that the countries that will succeed in productivity and employment growth are those which diversify into more complex products, industries with high innovation and learning potentials, and sectors with high domestic and external elasticity of demand (Cimoli, Dosi, and Stiglitz, 2009; Hausmann et al., 2013; Salazar-Xirinachs, Nübler, and Kozul-Wright, 2014).

Moreover, Pérez and Soete (1988) suggested that times of technological change open up "windows of opportunities" for catching-up countries. Those countries will be able to benefit from such opportunities, which build up the capabilities required to transfer technologies, imitate, innovate, and learn to compete. The reason is that the transfer of technology to a domestic enterprise is not like transferring a physical product. It is fundamentally a learning process. By accumulating sector-specific knowledge and competences in relatively low-technology activities within a particular sector, workers and enterprises can develop the capability to diversify gradually into the more sophisticated and higher technology activities, which provides further learning opportunities. With increasing diversity and complexity of the knowledge base and competences of workers and enterprises, they will eventually

FIGURE 5:
DYNAMICS OF CHANGE IN THE DISTRIBUTION OF ROBOT STOCKS ACROSS THE ROBOT-INTENSIVE INDUSTRIES (PERCENTAGE), IN SELECTED COUNTRIES, 2008-2015



Source: International Federation of Robotics (2016).

be able to take advantage of opportunities arising from newly emerging cutting-edge technologies. For example, Korea entered the automotive industry in the 1960s and when the new robot technologies (CAD) were introduced in European car factories, the Korean firms were able to adopt this technology, learn to compete, and eventually to develop a national automobile industry.

The recent wave of robotization in Asian middle-income countries suggests that these countries benefited from windows of opportunities that emerged with the new wave of digital robots and the global value chains (GVC) in the 1990s and 2000s. These countries attracted tasks in GVCs, workers and firms accumulated capabilities through learning and experience, and eventually, they were able to install robot technologies and produce more complex intermediate goods and also final manufactures. The experience in the middle-income countries in Latin America is fundamentally different. They followed a resource-based strategy of integrating into GVCs, shifted out of industrial products, and lost out in economic complexity.

Figure 3 demonstrates the changes in economic complexity in these two regions. The economic complexity index (ECI) was developed by Hausmann et al. (2013) to measure the sophistication of a country's export products. Between 1998 and 2008, economic complexity declined in all South American countries (except in Ecuador). These different trends in economic complexity resulted in the relative high robot density in the South East and East Asian countries, and in the very low robot density in South American countries in 2008.

Most interestingly, while countries in both regions experienced high growth rates in robot density between 2008 and 2014, they differed significantly in the sectoral structure of robotization. Table 1 shows that industries differ substantially in robot intensity with transport equipment being by far the most robot-intensive sector, followed by chemicals and plastics, electrical and electronic products, and metal products. In contrast, textile, footwear, wood and furniture, and paper show extremely low use of robots in production. This implies that the pattern of structural change is important for a country's potential to increase its robots' density, productivity, and complexity.

Figure 4 shows how each region has distributed its stock of robots across industries. The middle-income countries in the South East Asian region have a relatively large part of their robots in both the transportation (e.g. automobile) and electronics industries. The properties of these two industries provide good opportunities for catching up in economic complexity. In fact, both industries demonstrate elastic demand, they are highly fragmented and they are produced in GVCs. Latin America and Central and Eastern European countries, in contrast, concentrate most of their robots in the transportation industry. The United States is the only region which also developed a significant share of robots in the electrical/ electronics industry. It is most interesting to observe that Mexico is the only Latin American country which was able to accumulate some share of robots in

11.7%

THE AVERAGE SHARE OF INDUSTRIAL EMPLOYMENT IN THE MAJOR ECONOMIES IN LATIN AMERICA AND THE CARIBBEAN

the electronics industry (see figure 5).

These findings suggest that the rise of global production systems and increasing global demand for electronics provided windows of opportunity for developing countries to diversify and catch up in robot density and economic complexity. It was low-cost Asia which had developed capabilities to attract activities in electronics and to develop into the main producer of electronics and the supply chain shifted towards ASEAN countries.

Figure 5 complements this analysis and shows the dynamics of change in the distribution of the robot stocks across the robot-intensive industries for selected countries. While the industrialized countries Germany and Korea show a relatively low dynamic in changing the distribution of robots since 2008, the middle-income countries are more dynamic. Comparing column 1 and 2, however, shows that the high performing Asian countries China and Thailand demonstrate a significantly higher dynamic when compared to the high performing countries in Latin America, Brazil, and Mexico.

The magnitude of changes in the relative distribution of robots across industries is extremely high in China and Thailand. In China, the absolute number of robots increased rapidly in all robot-intensive industries. However, the share of robots in the car industry increased most dramatically, and to a much lesser extent in the metal and electronics industry, which is mirrored by the rapid decline of the share of robots in the plastic industry. Thailand seems to follow a similar dynamic. In other words, it is plausible to conclude that the Asian middle-income countries could develop such dynamics in accumulating robots in different industries due to the capabilities which they developed during the period of increasing economic complexity (the 1990s and 2000s).

The important question is how these two strategies have affected employment in manufacturing. Figure 6 shows that employment in manufacturing (as a share of total employment) declined in all countries in the Latin American region. The average share across these countries declined from 14.7% in 2000 to 11.7% in 2015. In contrast, the average share of manufacturing employment in Asia remained unchanged, 13.4 and 13.3 respectively. While China, Malaysia, and the Philippines decreased the share of manufacturing employment, they increased in Thailand, Vietnam, and Indonesia. This is explained, among other factors, by the capabilities they had accumulated during the 1990s and 2000s, which enabled them to shift into more robot-intensive tasks within the sectors in question.

DISRUPTION AND CATCHING UP

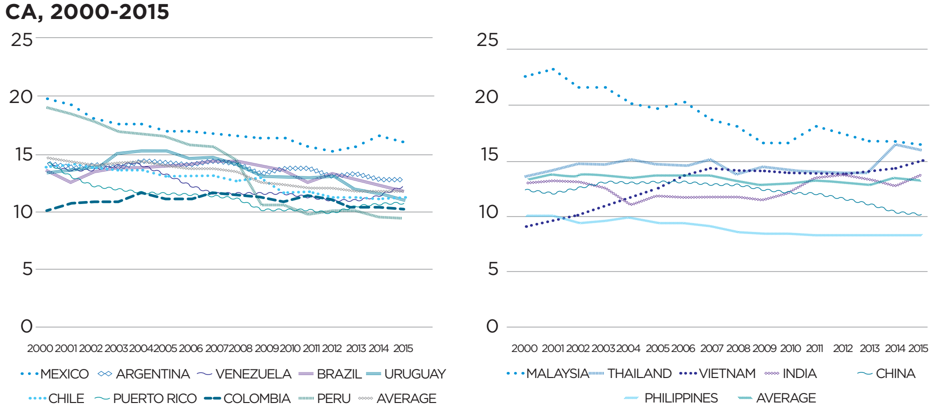
Innovation in robot technologies and the wide diffusion of robots in production will not only destroy jobs but will have a variety of different effects on economies and societies. They have the potential to increase unemployment, enhance the complexity of skills, polarize jobs, and widen inequality. These effects create winners and losers and possibly threaten social cohesion. At the same time, markets find ways to adjust, expand, and create new jobs, while creative entrepreneurs use new robot technologies to develop new goods and services and, in developing countries, create activities in robot-intensive sectors, thereby catching up and creating productive jobs.

This process of creative destruction, reflected in adjustment, diversification, and structural transformation, is complex, costly, and uncertain, and it cannot be achieved by markets alone. Governments need to design comprehensive policy packages and develop new institutions which need to take into account country-specific conditions and social aspirations. The main message is that the future of work is not deterministic; it needs to be shaped and this requires economic, societal, and political forces.

First, robots have disruptive effects on labor markets and societies, and, therefore, policymakers are challenged with facilitating and managing adjustment processes to mitigate these effects. While some workers gain from robotization, others have to bear the burdens of losing jobs, declining wages, or deteriorating working conditions. Social justice requires policies to create a balance between

FIGURE 6

CHANGE IN MANUFACTURING EMPLOYMENT, AS A SHARE OF TOTAL EMPLOYMENT (%), IN MIDDLE-INCOME COUNTRIES IN SOUTH EAST ASIA AND IN SOUTH AMERICA, 2000-2015



Source: Trends Econometric Model database, ILO (November 2016).

those winning and losing. Moreover, active labor market policies need to support workers in moving to new jobs and enhancing their employability. Social protection allows workers to search for new productive employment, invest in skills, and maintain consumption demand. In this context, universal basic income is discussed as a policy counter-measure. Moreover, fiscal policies may help to mitigate the disruptive effects of rapid robotization by slowing down job displacement and providing space and time to learn and adjust. Taxing robots is discussed as one possible instrument.

Second, policymakers need to manage the dynamics of productive transformation and the job-creating process. Robot technologies provide opportunities for creative entrepreneurs to invent and design new products, and they open up windows of opportunities for enterprises in developing countries to catch up through robot-intensive industries. While market forces play an important role in this process, they need to be strengthened, coordinated, and supported by policies and institutions.

"New" industrial policies, when properly designed and implemented, enhance the dynamics of product innovations, create new productive jobs in robot-intensive industries, and create jobs in other sectors. Policies may also support R&D to support the design of innovative collaborative robots to be exploited in the artisan and crafts sector in producing customized goods and services.

Wage and fiscal policies also play a key role as they need to ensure that productivity gains arising from robotization are shared in a way that supports the job-creating adjustment processes. They need to increase demand by translating productivity gains into higher wages, falling prices, or reduced working time. When higher profits are invested in R&D and new types of robots, jobs will be created in the capital goods and software industry. Fiscal policies distributing higher productivity to creative entrepreneurs will support investment in start-ups and new business models exploiting Big Data and Artificial intelligence.

Finally, while the installation, use, and maintenance of robots in an enterprise requires skilled workers, in particular at the middle occupational level, the diversification into new products and even industries requires a broad range of competences at the individual, firm, and societal levels. These collective or social capabilities enable a country to drive and manage transformative change. Such dynamic capabilities are embodied in formal and informal institutions, as well as in the particular mix of knowledge, attitudes, mindsets and belief systems of a society. Evidence suggests that those developing countries will be able to take advantage of windows of opportunities arising from the emerging autonomous, collaborative, and learning robots that have developed the right set of capabilities. This challenges policymakers to design policies and develop institutions that promote SMEs, technological learning in enterprises, R&D, craftsmanship, and entrepreneurship.

Education, training, and learning at the workplace are critical, as they are major determinants of a society's knowledge base and social capabilities. Education and training policies need to go beyond increasing levels of education. They need to be concerned with building up a complex and diverse knowledge structure in the labor force, as well as attitudes and mindsets, that enable firms to innovate in new robot technologies and create productive and decent jobs. Institutions for social dialogue will be of critical importance as they help to forge a new consensus in society on the future of work, and the social and political choices that will shape the transition to this new future.

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CASE STUDY

3D PRINTING FOR HOUSING

A DISRUPTION THAT'S SHAKING THE CONSTRUCTION INDUSTRY RIGHT DOWN TO ITS FOUNDATIONS

Automation and robotics have arrived in the world of construction, one of the most labor-intensive sectors of the economy. The Chilean company BauMax uses an automated, concrete-based construction system that substantially increases productivity and promises to reduce building costs and times while improving quality and access to housing. The system also impacts the environment less than traditional construction as it generates less noise pollution and rubble.

General manager Pablo Kühlenthal describes how this alternative model works, the training that professionals need to use it, and how it will impact the Chilean economy.

What changes will this new construction technology bring?

Ours is the only robotized technology in Chile that creates concrete structures using a carousel factory. The system includes different stages where each building panel is printed. Each step in the process is managed without the need for human intervention. We are hoping to demonstrate the benefits that this cutting-edge system will bring to Chile. Property developers and construction companies aren't the only ones who stand to benefit: it will also help the country meet its social needs, as a way of building hospitals, jails, and low-income housing.

What challenges does this new technology bring?

In Chile, we've been using human labor and bricks to make buildings for over a century. This system aims to complement the existing approach and renew or replace aspects that are becoming obsolete. One of the major advantages is construction time, which is considerably shortened. Flexibility is another factor: the units are manufactured as complete components that can be efficiently put together on-site This reduces rubble and the environmental and noise pollution that current construction systems generate by more than 30%. Another significant short-term impact of the BauMax construction process

30%

REDUCTIONS IN CARBON DIOXIDE EMISSIONS IN THE INDUSTRY

will be improved housing quality and integration with building information modeling (BIM) software. Things will also change for real estate developers, who will be able to build projects in shorter stages and adjust these to the pace of sales or the state of the economy.

How does the system improve productivity?

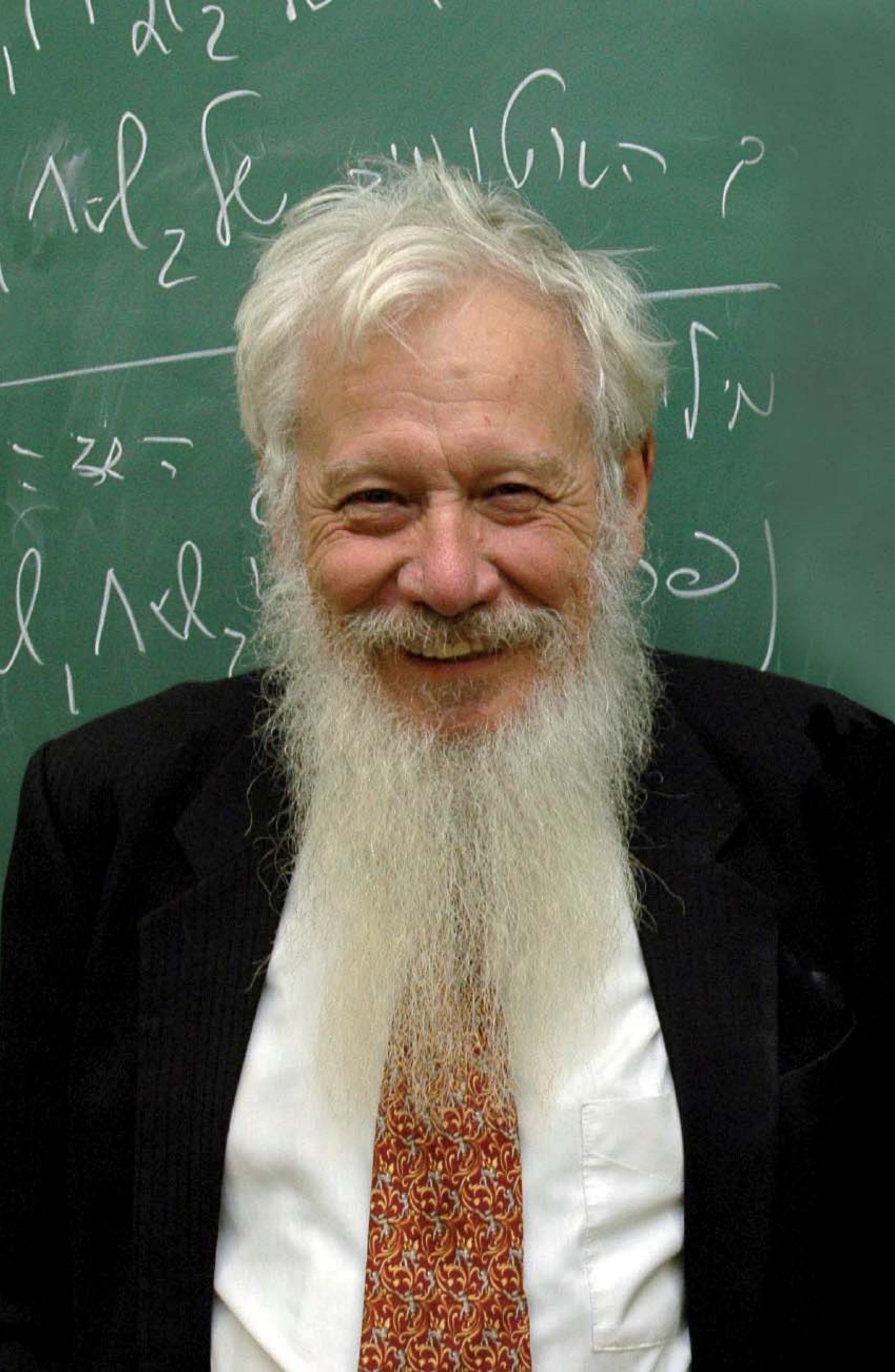
There is a significant productivity gap between Chile and developed countries. This gap is even wider in the construction industry—as large as 48% in comparison with the United States. This outlook is disastrous and merely confirms that any project that substantially improves productivity in the construction industry has real potential. Thanks to our small but highly skilled team, we can produce up to four 140-square-meter houses in a single day through innovative technology that produces concrete components via a robot that creates them directly from the BIM model, with no room for error. We get finished batches to construction companies quicker, which helps them build more agile structures.

What sort of knowledge is needed to operate these new machines?

Everyone involved in robotized construction has had to adapt their work to this automated system that was first developed in Germany. Right from the outset, during the design stage, architects have had to adjust their designs to the needs of different construction companies, the carousel mold, and the BIM project. During the production stage, workers have specialized in the use of iron bars, concrete, and software to keep the process flexible and ensure structures are perfect.

Is human labor compatible with that of robots? Can they work alongside one another?

Anyone who gets involved in robotized construction needs to acquire new specialist knowledge to adapt their existing skills to new technologies and be fully involved in these processes to reap their benefits.



INTERVIEW

"The keys are **education** and the **incentive system**"

Robert Aumann

Nobel Prize in Economics

Robert Aumann was awarded the Nobel Prize in Economic Science for having expanded understandings of conflict and cooperation in game theory. For this American-Israeli mathematician, the aim of any successful policy should be creating adequate incentives. In an exclusive interview with *Integration & Trade Magazine*, Aumann insisted that the future of our societies will depend on how willing we are to invest in education.

How can innovation in new technologies serve sustainable development?

The most important factor in innovation is education. If you educate people, you get good results. The key to development in the United States, Israel, Latin America, and anywhere else on earth is education.

What types of public policies contribute to the incentive system for entrepreneurs? What sorts of regulations are needed?

Forget about regulations. Prohibition doesn't work, people ignore regulations. It comes down to three things: incentives, incentives, incentives. Public policies are all about creating incentives. They're not about regulations that completely prohibit something. On the contrary, they're definitely about generating incentives because things generally work much better that way.

THE KEY TO INNOVATION IN ANY COUNTRY IS EDUCATION

How can game theory contribute to designing better technology policies?

The fundamental principle of game theory is for everyone to act according to their incentives. That's the basis of game theory, and, indeed, of any economic theory. We need to give people the right incentives while being very careful about the incentives that we create. Let me give you an example. There was a beautiful jungle in the south of Nepal which was very rich in biodiversity. It had a great many plant and animal species and was a true Garden of Eden. But it also had mosquitoes, specifically the *Anopheles* mosquito, which spreads malaria. People thought that if it was a beautiful jungle and the only bad thing about it was the *Anopheles* mosquito, why not wipe it out? Then it really would be paradise. So they fumigated the area and eradicated the mosquito. Before long, the jungle began to fill up with homeless people, poor farmers, and industrial developers, who all moved in now that it was no longer dangerous to do so. The settlers cut down trees and planted crops and after just five years, there was no more jungle. We need to understand that we must always ask ourselves, whenever we do anything, what new incentives we are creating and what the consequences of our actions will be. In this case, pesticide use

ROBERT J. AUMANN WAS BORN IN GERMANY IN 1930. HIS FAMILY EMIGRATED TO THE UNITED STATES IN 1938, TWO WEEKS BEFORE KRISTALLNACHT. HE RECEIVED HIS PHD FROM THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT) IN 1955. IN 2005, HE WAS AWARDED THE NOBEL PRIZE IN ECONOMICS WITH THOMAS SCHELLING. HIS MOST IMPORTANT SCIENTIFIC PUBLICATIONS INCLUDE:

· VALUES OF NON-ATOMIC GAMES. PRINCETON: PRINCETON UNIVERSITY PRESS (WITH L.S. SHAPLEY). 1974.
· LECTURES ON GAME THEORY. BOULDER: WESTVIEW PRESS. 1989.
· HANDBOOK OF GAME THEORY WITH ECONOMIC APPLICATIONS. AMSTERDAM: ELSEVIER. 1992.
· REPEATED GAMES WITH INCOMPLETE INFORMATION. CAMBRIDGE, MA: MIT PRESS (WITH M. MASCHLER). 1995.

destroyed not only the mosquitoes but the jungle, too.

At first glance, it's hard to think of combating malaria as a bad thing.

Let me give you another example. The Pantanal area in Brazil, which is a huge tropical wetland, is teeming with wildlife: bird, plant, and animal species, including leopards. The Pantanal is not a national park. There are farmers living there that raise cattle, and from time to time, leopards kill a cow or two. To stop this from happening, the farmers decided to hunt these leopards down and kill them, which led to them becoming an endangered species. So what happened next? Other people wanted to save the leopards, so they created an organization that would pay farmers more than what a cow was worth if they showed up with the remains of one that had been attacked by a leopard. As you can imagine, the farmers quickly stopped killing leopards. In fact, they started wanting them to come and hunt their cows because the incentive for having a cow that had been killed by a leopard was greater than that of raising the cow.

Do incentives work better to make people do things or stop doing them?

It's the same difference. Let me give you another environmental example. In Switzerland, where I often go on skiing holidays, the garbage you place in the designated neighborhood containers must be in official trash bags that you have to buy. These bags are provided by the government and cost around five Swiss francs each—a lot of money for a single plastic bag. All nonrecyclable trash must be thrown away in one of these bags. This very quickly created an incentive to reduce waste by doing things like using fewer disposable plastic plates and other products that harm the environment. If you have to pay five francs for every bag of trash that you throw away, it discourages the use of disposable products. As people no longer buy these things, producers stop making them, they become scarcer and more expensive, and that opens up a way back. Saying "This is allowed" or "This is forbidden" doesn't work. You need to create the right incentives to make the things you want happen.

ANALYSIS

Toward a universal

Cristina Calvo
University of Buenos Aires

citizen income

This consumer society, which is blinded by the market, will be followed by another that will be defined by the momentous fact that it will not overlook social justice and solidarity.

René Favaloro

A UNIVERSAL BASIC INCOME OR A CITIZEN INCOME WOULD PROVIDE RELIEF FOR THE ENTIRE POPULATION BY RAISING THEM ABOVE A CERTAIN INCOME THRESHOLD WHICH COVERS THEIR BASIC NEEDS. AMONG OTHER THINGS, IT WOULD ELIMINATE INTERMEDIARIES, REDUCE INTRAFAMILY VIOLENCE, AND IMPROVE THE QUALITY OF LIFE OF THOSE WHO CANNOT ACT ON THEIR VOCATION BECAUSE IT IS NOT COMMERCIALLY VIABLE TO DO SO.

Between 2000 and 2014, average annual GDP growth in Latin America and the Caribbean was over 3%. In contrast to the global trend, income inequality during that period decreased in many countries in the region (figure 1.1, panel A), fundamentally due to the application of conditional income transfers such as Brazil's *Bolsa Familia* program. Lately, the region has been facing multiple external challenges caused by the end of the commodities supercycle, the slowdown in China's growth, and the gradual normalization of monetary policy in the United States. Due to these changes, and despite the heterogeneity within Latin America, standards of living in the region are no longer catching up so quickly with those of advanced economies and they are now falling behind again in some countries. The lack of structural reforms means that it is still common in Latin America for less-skilled people to be trapped in precarious and unproductive jobs, often within the informal economy (figure 1.1, panel B) (OECD, 2016).

In Latin America, as in most emerging economies, increasing productivity is a crucial part of closing the wide gap in standards of living between these and advanced economies and avoiding the middle-income trap. Although, on average, Latin Americans spend more time on labor activities than the OECD average, the relatively high share of the labor factor in GDP per capita is offset by the enormous difference in productivity levels (figure 1.2, panel A). Average labor productivity over the last decade reveals that, in most cases, the growth rate has only just been high enough to keep up with the pace of advanced economies and too low to significantly narrow the gap in standards of living (figure 1.2, panel B) (OECD, 2016).

An inclusive approach for Latin America would require governments to undertake deep structural reforms that would allow all people and companies to increase their productive potential to bring about a greater increase in aggregate productivity and a more equal distribution of income. A virtuous circle would require action to be taken simultaneously on social protection systems and factors that would put Latin America and the Caribbean on a path to social inclusion and sustainable employment. My focus in this article will be new issues in this ongoing debate, which include adding a citizen income (CI) to social protection systems and connecting it with sustainable job creation.

A variety of public policy interventions are being implemented in the world with the aim of overcoming the scourges of poverty and destitution, be they widespread or specific. Up to now, none of these interventions have been entirely successful, and the achievements they have entailed have not been replicated in other contexts, where poverty comes hand-in-hand with social behaviors that are specific to each social environment.

Although poverty is multidimensional, one of its dimensions is the material and monetary aspect, which I view as the foundation on which all remaining interventions (those relating to health, education, labor, and relationships) should rest.

A LIFE OF DIGNITY

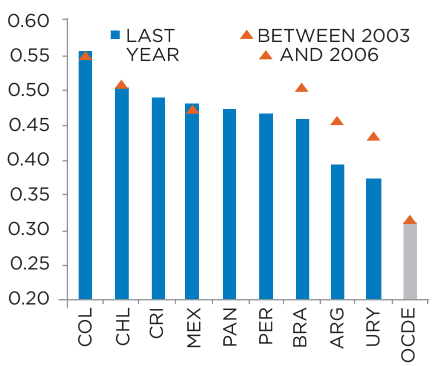
This context framed the discussion for the possibility of a universal basic income (BI) or CI for Latin America and the Caribbean. The aim of an instrument of this type is to provide relief for the entire population by bringing them above a certain income threshold which ensures their basic needs are covered. Among other things, this system would eliminate all intermediaries, except different payment mechanisms from within the financial system. Intra-family violence would also be reduced because the system would resolve the

7%

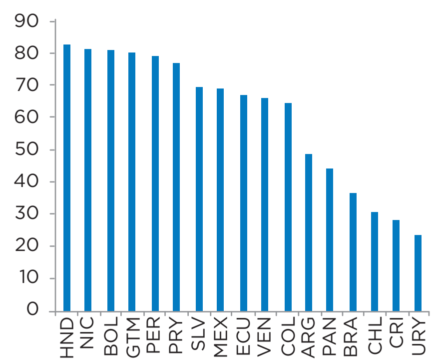
THE STRUCTURAL UNEMPLOYMENT RATE IN LATIN AMERICA

FIGURE 1.1
VARIATIONS IN INEQUALITY IN MOST LATIN AMERICAN COUNTRIES

A. GINI COEFFICIENT, FROM 0 (ABSOLUTE EQUALITY) TO 1 (ABSOLUTE INEQUALITY)



B. PROPORTION OF WORKERS IN INFORMAL EMPLOYMENT



Note: Gini coefficients are used as a measure of available income per home, except in Argentina, where per-capita income was used. The data for Costa Rica is preliminary. Workers employed in the informal sector represents workers who are not enrolled in a compulsory pension plan. Data is from approximately 2013. Sources: OECD/IDD, except for Brazil, Peru, Uruguay, and Panama (LIS) and Argentina (SEDLAC, CEDLAS, and World Bank); data from the IDB Labor Markets and Social Security Information System (SIMS) based on household surveys.

8%

THE AVERAGE ANNUAL INCREASE IN LABOR PRODUCTIVITY IN INDIA

monetary issues that impede victims from becoming economically independent from family ties. In addition, it would improve the quality of life for those who cannot develop their vocation because it is not commercially viable or because there is no real demand for it on the market, even if the work it entails is in short supply because the activities in question are not sustainable in terms of maximizing financial profit, as is the case with care for the elderly or people with different abilities, the activities of street musicians, artists in general, craftspeople, weavers, and many others. CI would provide a minimum income base that would allow citizens a life of dignity, regardless of whether they are able to work within profitable markets.

One of the key questions that come up when CI is discussed in the world is how this would be financed. Within Latin America and the Caribbean, in countries like Argentina, where the state commitment to social investment is high and there is a significant fiscal deficit, this question is crucial. For this reason, implementation strategies need to contemplate and prioritize the more vulnerable sectors of the population, who suffer from social exclusion, and then think about extending this coverage to the rest of the population when the financing mechanism for the system permits (following fiscal reforms).

The most widespread definition of CI is the unconditional payment of a sum of money that is unlike other subsidies in that, to be eligible for it, you do not have to meet any established conditions, such as being poor, unemployed, disabled, or elderly. Being a citizen or resident would be the only conditions for receiving CI.

A CI system is beneficial on at least two fronts: the psychosocial and the monetary. In psychosocial terms, it prevents the psychological and moral damage that arises from the social stigmatization of those who receive payments. In monetary terms, it implies savings on the administrative costs involved in targeting beneficiaries—the fact that the income is universal simplifies administrative procedures. CI can exist in parallel with additional income from a paid job, in that it is defined as a basic threshold on top of which people can accumulate any other sources of income.

I should point out that it would be foolish to discuss the possibility of moving toward a CI in Latin America without first reviewing the entire social protection system and the possibility of creating sustainable employment, given that this is a region where less-skilled people are trapped in precarious and less productive jobs, often within the informal economy.

Furthermore, the debate over the possible future implementation of CI in Argentina, for example, cannot be considered in isolation from one of the major gaps in contemporary economic theory, which is the lack of reflection on work in the 21st century. Such analysis needs to contemplate not only the replacement of human jobs through automation but also the very notion of work as a human activity and not just as a resource that functions in response to incentives and sanctions.

SOCIAL PROTECTION SYSTEMS

Social protection systems include all public policies that aim to prevent or protect the population from social risks such as poverty, unemployment, and informality, along with policies that aim to promote opportunities for human development. Although there are nuances in how such policies are defined locally, in Latin America and the Caribbean these include social security policies such as retirement and pension programs; unemployment benefit; contributory and noncontributory family allowances; active labor market policies; conditional income transfer programs; and service provision, such as labor intermediation and employment-related and professional training.

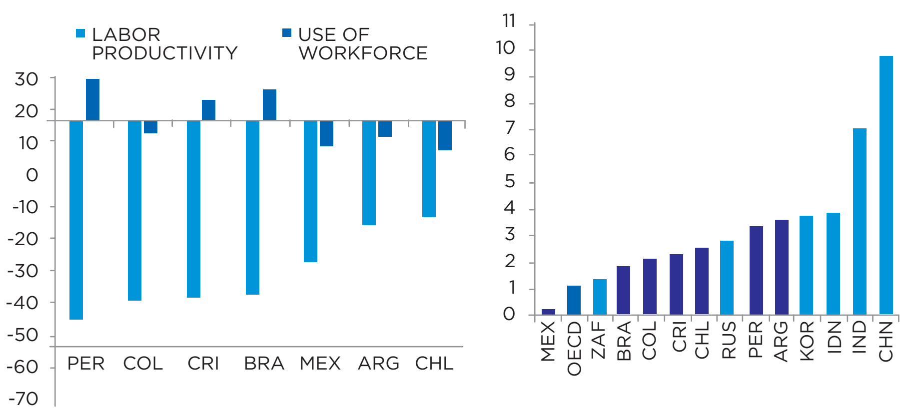
Given the divides and social debt in the region, we need to redouble our efforts if we are to move decisively toward equal opportunities and the universalization of rights. Latin America remains the most unequal region in the world. This implies challenges in terms of monetary income and in relation to gender, ethnicity, and territory. Among marginalized groups, employment tends to be precarious and does not function as a vehicle for social mobility and welfare. Furthermore, labor conditions among broad sectors of the population differ greatly from those enshrined in the regulations governing decent work and do not guarantee access to social protection mechanisms.

Social protection is a factor that differentiates social policy from other pol-

FIGURE 1.2
GAPS IN PER-CAPITA GDP WITH ADVANCED ECONOMIES ARE MAINLY EXPLAINED BY LOWER LABOR PRODUCTIVITY

A. PERCENTAGE DIFFERENCE WITH OECD AVERAGE, 2013

B. AVERAGE GROWTH IN ANNUAL LABOR PRODUCTIVITY, 2003-2013



In Panel A, labor productivity is expressed in GDP per worker. The use of workforce is the ratio of the active population over the total population. In Panel B, labor productivity is expressed in GDP per hour worked.
Sources: OECD National Accounts Database, OECD Economic Outlook Database.

icy areas and requires that both governments and citizens take responsibility for it as, to put it simply, it relates to the care that society provides for its members. A simple social protection system should fulfill at least three essential functions: a) ensure that all people have the resources necessary for guaranteeing human dignity and a healthcare system that provides universal coverage; b) try to favor the social integration of the inhabitants of a territory and their access to the labor market; c) provide workers who have reached retirement age or who have to interrupt their activities due to illness, an accident, childbirth or childcare, injury, or unemployment a substitute income that allows them to maintain a decent standard of living (Gómez Paz, 2011).

Within social protection systems, conditional transfer (CT) programs deserve a special mention. These were an important public policy innovation that began in the mid-1990s. Instead of giving general payouts, controlling prices, or distributing food directly to help the poorest sectors of society (three instruments that were inefficient, distorting, and generally regressive), governments began to distribute money directly to the poorest families, making these transfers conditional on their children attending school and/or health check-ups. Evaluations show that the programs had the desired effect (that is, families began to consume more, without there being evidence of any negative effects on the labor market, while the use of health and educational services also increased), but they have also come under scrutiny for a variety of reasons. The best-known in Latin America are the Universal Child Allowance (Argentina), *Bolsa Familia* (Brazil), Ethical Family Income (Chile), *Red Unidos* (Colombia), and PROSPERA (Mexico).

These programs have undergone different reforms since they were first implemented with a view to making them more universal and rights-oriented. Other criticisms of the programs have been related to the fact that the health- and education-related results have not been uniform; even with CTs, there is a gap in the high school enrollment rate; many gender inequalities have not been sufficiently eliminated; and many countries increased their public deficit to finance these monetary transfers without modifying the structural conditions that enable citizens to get out of poverty. These criticisms go beyond transfer programs. These programs are tools that should be part of a broader social strategy that, along with other public policies (with a focus on productivity, taxation, innovation, and redistribution), contributes to breaking the intergenerational transmission of poverty (ECLAC, 2011).

TEMPORARY OR PERMANENT

This study discusses citizen income (CI) as it is the term most frequently used in Latin America and the Caribbean, but it is equivalent to the concept of basic income (BI) that is frequently used in the literature and analyses of the Global North. BI is mainly used to refer to what I will later define as the "minimum income for integration."

A simple definition of CI is: "an income paid by the state to each member of society as a right of citizenship, regardless of whether they work, whether they are rich or poor, or, in other words, independently of any other forms of income they may have" (Del Val Blanco, 2015).

BASIC INCOME

A PAYMENT FROM THE STATE WHICH ALL CITIZENS HAVE A RIGHT TO

Social protection is often analyzed from a reductionist standpoint, especially when it comes to programs that aim to alleviate the situation of the unemployed, and it is argued that those receiving some kind of help from the state are discouraged from seeking work. Although this may be true, the problem arises when social support, instead of being temporary and functioning as a bridge toward genuine work or economic activity to support life, becomes permanent and ends up creating a form of dependence that is not in keeping with true human development. There have been some negative experiences in relation to support programs that failed to reduce poverty for decades and often became a source of political/electoral profit rather than a way to assist vulnerable sectors of society. In Latin America, structural unemployment levels stand at about 7% (without including precarious underemployment, wage workers living in poverty, and other categories), so social protection needs to be accompanied by active policies to prevent the social exclusion of the structurally unemployed, those who have been left out of the labor market due to their limited skills, the elderly, and people with disabilities.

Descriptions of CI tend to make the following distinction (Gómez Paz, 2011).

a) Minimum guaranteed income: an economic benefit intended to guarantee access to a minimum standard of living that is independent, widely accepted, and to which all citizens have an unconditional right without needing to do anything in return.

b) Minimum income for integration: an economic benefit that seeks to satisfy basic needs but is closely connected to the social and labor integration of those who receive the subsidy, such that it ceases to be paid to them once they have become integrated into these systems.

CI schemes spark debate in both developed and emerging countries. Analysts from different ideological backgrounds ascribe different benefits to it: from a structuralist perspective, a CI gives the unemployed population a better chance of joining the labor sector; in terms of gender and equality, a CI levels opportunities for women, the elderly, the young, and those with disabilities in comparison with other segments of the population; and from a neoclassical economic perspective, CI improves the relationship between employers and employees.

Freedom and Autonomy

High levels of poverty and inequality persist in Latin America and the Caribbean, despite the significant progress made toward reducing these up to 2013. This situation prompts the need to design a new style of development that would also imply profound modifications to welfare regimes and social policies. We need to abandon the narrow vision of a social policy that is only concerned with reducing poverty and instead frame it within a much more ambitious objective: providing people and communities with ways to expand their freedom, skills, and autonomy.

TAXES ON ROBOTS AS A SOURCE OF FINANCING

In February 2017, Bill Gates surprised the world with his proposal to tax the work of robots when these begin to threaten to replace human labor. He sees such taxes as a way of redistributing wealth that would prevent people from being afraid of innovation because they see it as a threat to their livelihood. It would even be an act of tax justice because robots do not pay income tax like human workers do. Benoît Hamon, the leader of the French Socialist Party and a candidate in the 2017 presidential elections, expressed his support for the initiative and proposed a tax on robots to finance a minimum income for all. These ideas do not sound quite so outlandish if we frame them in the message that the managing director of the International Monetary Fund, Christine Lagarde, gave at Davos. On April 17, 2017, at a conference at the Solvay Library in Brussels, Lagarde stressed the need for a more resilient global economy with more enduring and inclusive sustainable growth, economic policies that promote a form of growth that stresses productivity, a more equal distribution of benefits, and international cooperation through a multilateral framework. At the conference, Lagarde expressed her concern that automation might gradually put the growth of employment at risk. Given that robot labor will increase the profitability of the productive and service sectors in which it is implemented, the proposals from Bill Gates and others to tax robots is an indication of how urgently we need to restructure tax and social security systems, including CI, to create a more equitable distribution of wealth that translates into more decent standards of living for those who are excluded from the system.[1]

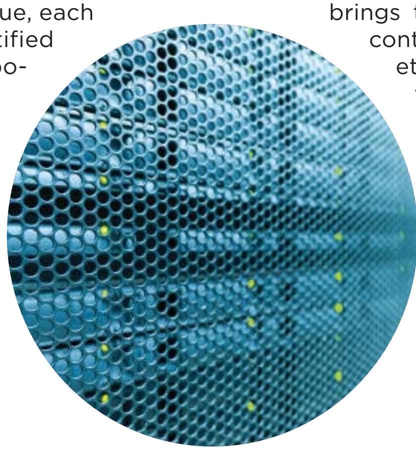
A new style of development would imply profound transformations to the way we produce, distribute, and consume. What is needed is a gradual structural change that achieves sustainable levels of economic growth based on productivity increases, the intensive inclusion of knowledge and innovation, the creation of value added, and the fair distribution of the benefits deriving from these improvements. CI schemes are at the heart of the debate around a new style of development prompted by uncertainty around global economic growth; profound transformations in the world of work, the consequences of which have not yet been fully identified or predicted; the limits of CT programs; and the spread of the rights-based approach to social policy, which links effective access to rights to being a citizen rather than to being in a situation of need or having a certain employment status (Bárcena, 2016).

An article by Carlos Otto published on April 17, 2016, in the technology section of the website for *La Vanguardia* had a surprising title: "Why Basic Income Is Being Discussed in Silicon Valley (and Why It Makes Sense)." One of the surprises that CI and BI are bringing is that Silicon Valley—a global tech mecca which is defined by economic liberalism and is home to companies like Google, Facebook, Apple, Amazon, and Twitter—should be part of a discussion that has historically been the realm of the ideological left. The reason lies in the possibility of using BI to protect and provide for people who are unemployed or lose their jobs to automation.

This prompts two interconnected discussions: discussions of BI in this context stem from an issue that is currently causing great concern, namely the repercussions of automation on work and the debate around whether robots will create jobs or destroy them. There are two fairly clear positions in this debate. On one side are the prophets of doom, whose arguments are based on the study *The Future of Employment: How Susceptible Are Jobs to Computerisation?* (Frey and Osborne, 2016), drafted by various researchers at Oxford. According to their report, 47% of jobs are at risk of disappearing, which will affect not only low-skilled work but also those with medium-level skills. On the other side are the tech enthusiasts who predict that many new jobs will be created. The most interesting aspect of this debate relates to the role of BI as a protective measure for those without a job and how technologies affect work. There are three clear ideological stances on this issue, each of which can be identified with a particular proponent or advocate.

The first is Paul Graham's position: this investor in Silicon Valley technology companies advocates for a BI for people who have lost their jobs due to automation. He has even created a research team to study and analyze BI models and their implementation among this group. Others disagree with the use of a BI in these circumstances, interpreting it as a compliment to the most aggressive forms of capitalism and economic liberalism, which will increase economic inequality, as these people will be condemned to a permanent state of precariousness. Likewise, large technology companies will have more power, as evidenced by the growing gap between wages and productivity from the 1980s onwards due to the growing importance of technological development.

Second, another advocate for BI, in this case in an unconditional, universal form, is Federico Pistono, entrepreneur, conference speaker, a graduate of the University of Verona, and a consultant for governments and *Fortune* magazine. He argues that automation will put paid to a high percentage of jobs but will also do away with many of today's worries regarding whether our wages will cover our daily needs. CI should allow any citizen, not just those that have been excluded from the labor system, to live with dignity, without being tied to a job that is often alienating, allowing each citizen to do what brings them satisfaction and contributes most to society. This position limits the role of the state to paying this unconditional income—it could eliminate all other social aid programs, which Pistono argues are more expensive and less efficient than CI.



The third position is best represented by Paul Mason, a writer and BBC journalist who is best known for his postcapitalist analysis defending the possibility of moving toward a world without work (which would also be a happier world). His theory is based on the idea that capitalism overexploits workers and consumes too many natural resources, which has brought it to the brink of its own destruction. In fact, Mason understands that the automation of employment will act as a way of freeing citizens from the pressure of work and allowing them to abandon capitalism in favor of a fairer economic system. In his view, the employment cuts that could come with the automation of work will not be a problem, as technology is bringing down product prices and also reducing our need to consume. CI would enable the average citizen to live a comfortable life of dignity.

These are some of the ideas and stances that could serve to intensify the debate on the implementation of CI from different ideological positions, based on different arguments and objectives, and with different scopes of coverage, which range from the broadest possible universe and include all citizens unconditionally, to a more limited target group made up of those workers who have been replaced by robots. In any case, theories in favor of CI are influenced by the potential consequences of automation on work, specifically how it will reduce job numbers (Viruez, 2016).

Proposals for Implementation

Numerous pilot experiences are being designed or developed in different parts of the world. Until a few years ago, this debate centered mainly on so-called poor countries, but today these experiences are being tested in Finland, Canada, Netherlands, and the United States, among others. In other words, they are part of a rethinking of social security, human development, and sustainable employment, even within high-income countries. It is worth pointing out that different pilot experiences are mainly examples of the minimum income for integration programs described in the third part of this article.

The type of CI that I have defined as an unconditional right of citizenship has only ever been implemented in Alaska. In 1976, an investment fund was established into which oil companies were to pay part of the profit they were making from extracting petroleum, as a form of compensation for local inhabitants for extracting a nonrenewable resource. Although CI was not part of the design when this fund was created, the aim was to establish an enduring mechanism of justice that would transform the extraordinary income from the oil boom into a perpetual source of income. Money was paid into the fund each year, and the Alaska State Legislature divided the profit among the state's adult inhabitants according to a pre-established formula, regardless of how many children they had or their employment status. Up to 2015, Alaska was not only one of the richest states in the United States in terms of income per capita but it was also one of the least unequal. However, in 2015, when oil prices dropped by more than half and Alaska was facing a growing fiscal deficit, the state was forced to seek other formulas for reducing expenditure and increasing income without depending so heavily on oil. This confirms that this type of instrument should be part of the decision-making process regarding the financing of a country's national budget.

One of the main objections that detractors make is that receiving an income that guarantees people's survival discourages them from seeking work, leaving no one to do low-skilled jobs. Various of the experiments that have been carried out have clearly demonstrated that the main beneficiary does not stop working even if he or she receives an income because the sums in question are not very high. We should now encourage the implementation of long-term experiences, because experiments lasting only a year or two are time-biased: if people know that they will only receive the income for a certain amount of time, they tend to take advantage of it to stay at home and look after their children, for example, rather than choosing to pursue education. However, if they know that they will receive the income for longer, they will plan the way they combine family care with education and continuing professional development differently, because people are aware that training is increasingly important and, even when you are employed, the challenge of new technologies and dizzying changes to the labor market force you to keep up-to-date.

The possibility of efficiently implementing and financing CI and maintaining this over time poses many questions. Is CI financially viable? Is it compatible with the social and political circumstances of our country? Does it strengthen citizenship? Does it encourage idleness rather than productivity? The historic urgency of solving structural social inequality issues in Latin America and the Caribbean undoubtedly points to the need to take on new mechanisms to implement social emergency policies, along with medium-and long-term human development policies. Citizen income is one alternative that should be part of this debate.[2]

NOTES

[1] Each day, the OECD calculates the fiscal cost of a CI for four European countries. On average, covering these would require cuts equivalent to 5% of GDP from other welfare benefits and a tax increase equivalent to 6% of GDP.

[2] This article is an early version of a longer study that will be published in late 2017.

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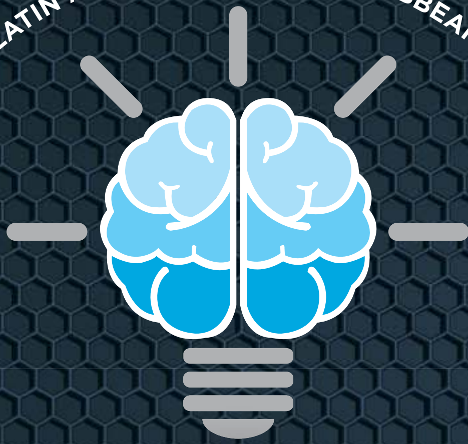

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- What skills will people need in the future and how can we rethink education for the coming generations?
- Can technological change play a part in reducing inequality in Latin America?
- How can the multilateral negotiation agenda be made compatible with the latest technology?
- What hopes and fears does the future of work conjure up among Latin Americans?