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Global Technology Flows 2030: Their Impact on Europe and the United States

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Introduction

Significant social and economic disruption occurs naturally as a technology or set of technologies flows throughout the world. One only needs to consider the advances in communications or transportation technology to appreciate the effects technology flows can have on how societies interact, economies function, and the earth system operates. Currently, *automation* from a particularly interesting set of electro-mechanical and information technologies, stimulated by hitherto unthinkable volumes of data, is poised to drive major disruption in the world.

Traditionally associated with manufacturing, automation technology today is spreading rapidly. Enabled by advanced algorithms, sensors, processing power, user interfaces, and new volumes of data, modern automation involves machines learning, thinking, and performing myriad tasks, both physical and knowledge-based, sometimes with minimal human intervention. These advances have far reaching implications: For example, recent research by the Oxford Martin School suggests that computers could replace humans in 45% of all U.S. jobs within 20 years.[1]

New data is underpinning this spread of automation. Estimates vary, but a reasonable consensus is that the world's data grew by 40-50% in 2013 and is likely to grow even more rapidly over the next two decades due to increasing digitization of work and consumer life, and the growing proliferation of sensors and connected devices (sometimes referred to as "The Internet of Things"). Cloud computing techniques already make huge storage capacities and supercomputer-level processing available on demand to anyone that needs it, and such capabilities will continue to accelerate.

[1] Frey and Osbourne, "*The Future of Employment*" (University of Oxford white paper, September 17, 2013).

A key but often-unrecognized implication of progress in big data and cloud computing is that machine learning is likely to evolve rapidly, leading to new types of automation. Most recent progress in artificial intelligence is driven less by the increasing brainpower of computer programmers (although steady, cumulative progress does occur) and more by the combination of increasing computer power, proliferating data, and cultivation of machine-learning algorithms that perform better the more data they can access. In 2011, Google's chief scientist, Peter Norvig, said, "We don't have better algorithms than anyone else, just more data." Given IBM's suggestion in 2012 that creation of 90% of the world's data took place in the prior two years, rapid progress in the capabilities of machine-learning algorithms in the next decade seems almost inevitable.

While the automation of manufacturing and the use of robots, drones, and driverless trucks have suggested a future where no physical laborers will be required, our personal spaces—the home, office, and car— are also becoming increasingly connected and in the future they will monitor and respond transparently and automatically to everyday human needs and wants.

For Europe and North America the impacts of advanced automation flows in the next 20 years will be particularly acute: Advanced automation will affect the competitive dynamics of many industries, the work tasks done by humans in both the product- manufacturing and knowledge-worker organizations, and how we personally interact with our physical environments and each other. In this chapter, we examine the advanced-automation technology flows and their impacts on the healthcare, financial services, and retail economic sectors in Europe and North American to highlight the possible positive and negative effects of future technology developments on economic and social systems.

Technology-Flow Foresight

This assessment of technology advances on the societies and economies of Europe and North America is based on SBI's analysis of new technologies in the U.S. National Intelligence Council's *Global Trends 2030* report. For the NIC report, SBI technology-commercialization experts applied SBI's scenario-planning and opportunity-discovery methods to identify the most-important new technologies in the next 20 years and assess their influence on the global system and U.S. interests.

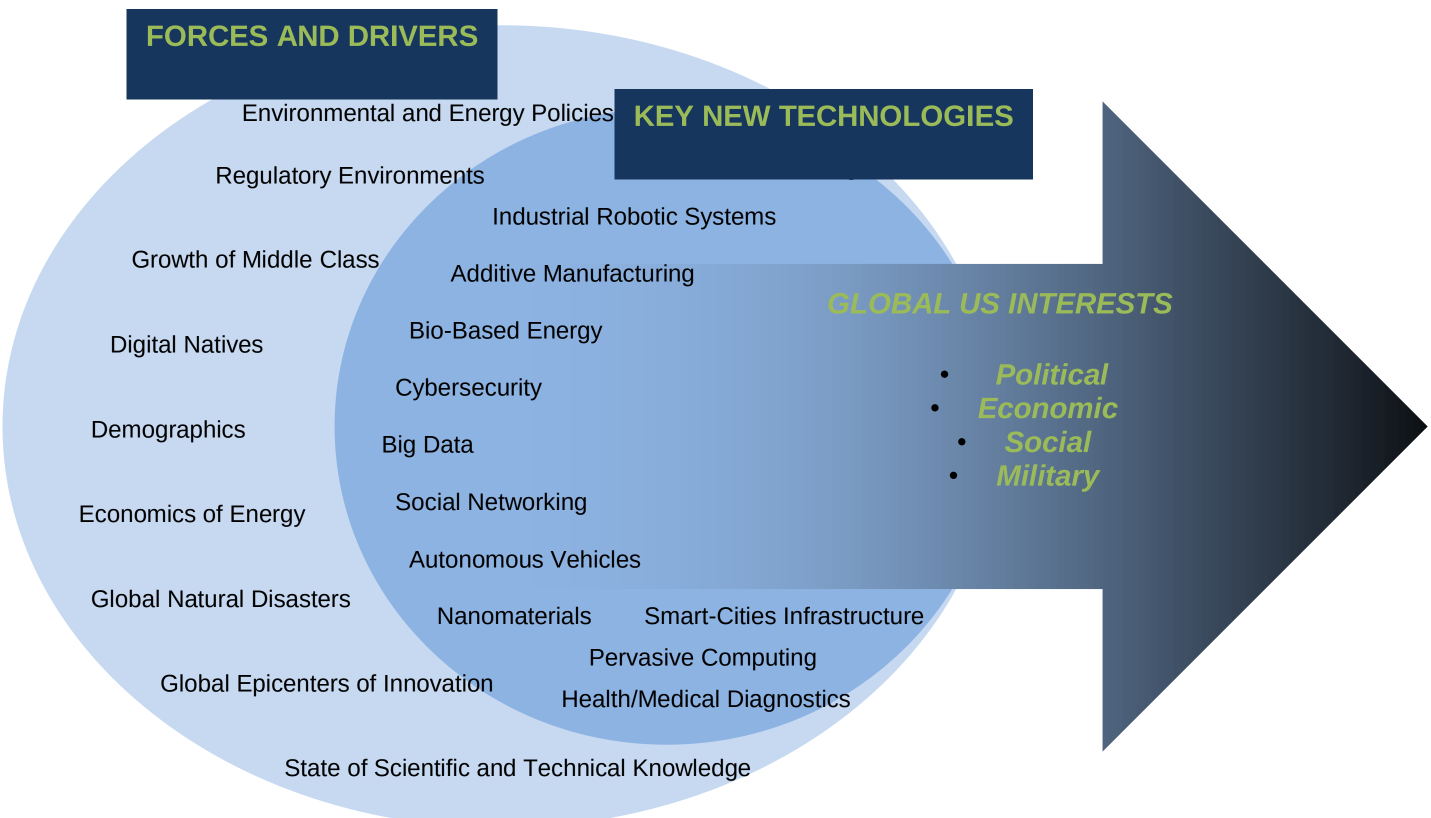
We also utilize Tomas Ries' flow-security framework[2] to help explain technology's role and impacts in the global ecosystem.

Technology flows are a result of a complex set of social, economic, political, and ecological forces and drivers where specific outcomes are essentially unpredictable because so many factors are involved. One can shape the conditions, motivations, and costs of technology development, but the range of possible winners and losers will always remain wide. Of the important technological factors that will be shaping the global ecosystem and the particular situation between North America and Europe in the next 20 years, the greatest has been and will be the emergence of the Chinese and Indian economies. As a result, the epicenters of technology innovation are moving toward Asia away from Europe and the United States. The biggest

[2] See Tomas Ries' chapter in this volume.

economic growth opportunities in the next 15 to 20 years will be in the emerging markets, where some business experts estimate annual consumption will reach $30 trillion by 2030. This growth will not only stimulate increased technology flows around the world; a shift in the technology center of gravity from West to East will likely occur. The big movement will come as multinationals focus on the faster-growing emerging markets and as Chinese, Indian, Brazilian, and other emerging-economy corporations rapidly become internationally competitive. The speed of this movement will depend on the availability of human and financial capital in the developing countries, rules of law to protect intellectual property rights, and the general desire of developing-economy companies to grow and be globally competitive. As of 2012, China is already the world's largest publisher of patents. This movement of the technology epicenter will change the dynamics of goods and services flows among the regions, but generally lead to increased flows of goods, services, capital, and information around the globe.

Figure 1. Global Trends Game-Changer: New Technologies

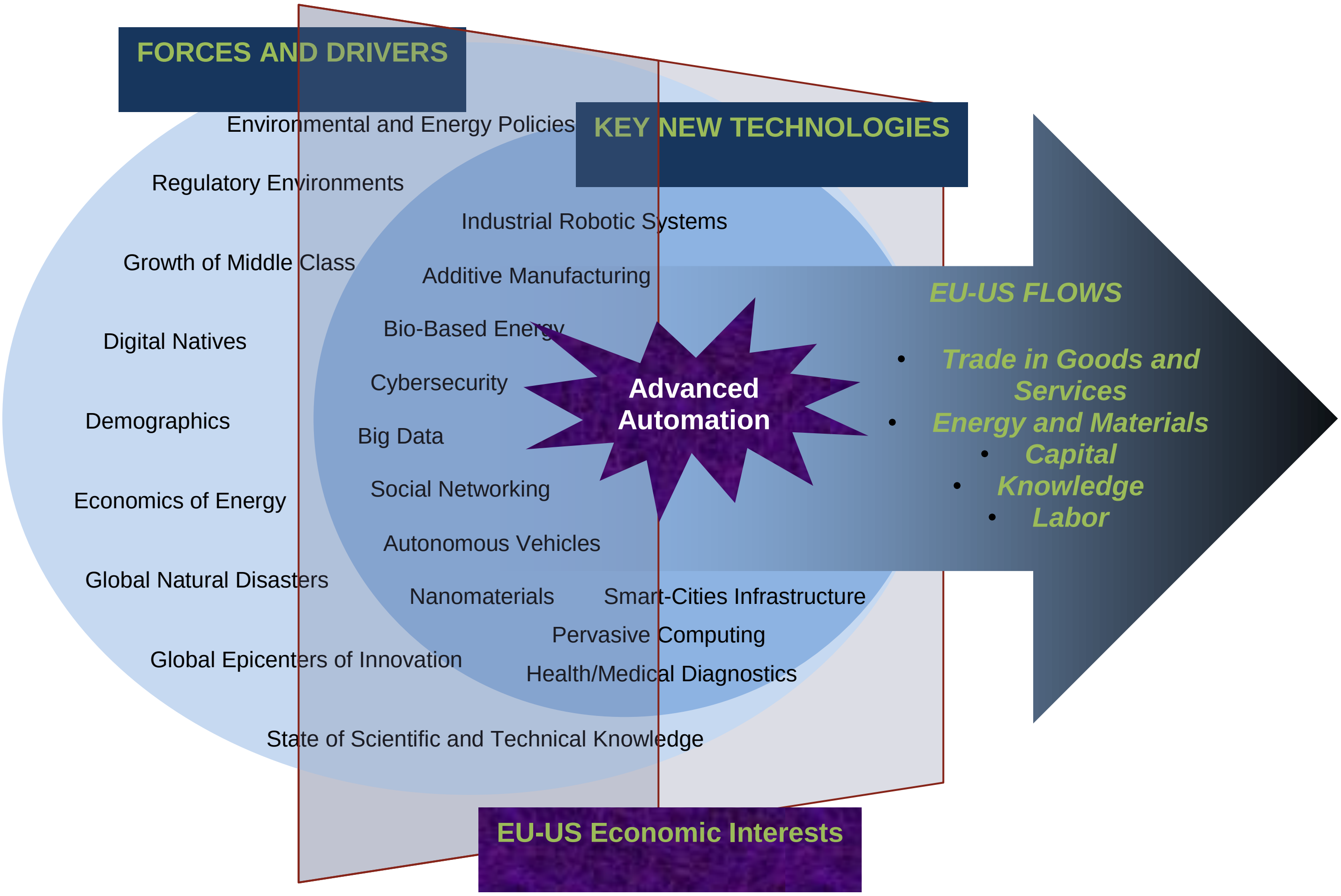


Given the present set of political, economic, social, and ecological conditions around the world, the flow of ideas, knowledge, and intellectual property related to technical advancements and innovations will likely increase in volume and speed in the next 20 years. Technology flows today are already fast and widespread in a global ecosystem because of the internet, mostly open global trade practices, global competition among large multinationals, open national higher education systems that encourage foreign students to attend, academic research conducted by researchers hired on the basis of academic merit, and international commercialization networks of the venture capitalists and other private equity firms. Science and technology research may be centered in the United States today, but teams of mixed nationality conduct it. In the future that research will be increasingly dispersed. Technology flow is a global enterprise, although developed countries led by the United States have dominated the picture because they have the legal systems that support innovation and developed countries are where the initial buyers are. A new technology flow in the last ten years has been reverse innovation, where the innovation initially occurs in an emerging economy and then spreads to the developed world, but this phenomena hasn't affected overall global flows much to this point. But in the next 20 years the sources of technology will increasingly be Asian and innovation could just as likely occur in the United States, Germany, and South Korea, as it could in China, Vietnam, and Turkey.

While technology flows stimulate economic flows, they also help expedite fast-moving economic cycles of boom and bust. While technology advances facilitate increased nimbleness by companies and government agencies alike, they also create problems of complexity that few can understand. Thus, an increase in technology flows produces a set of problems that work to undermine the future, and national leaders sometimes find it difficult to support globalization stimulated by technology because of the uncertainties and risks of economic downturns inside their borders.

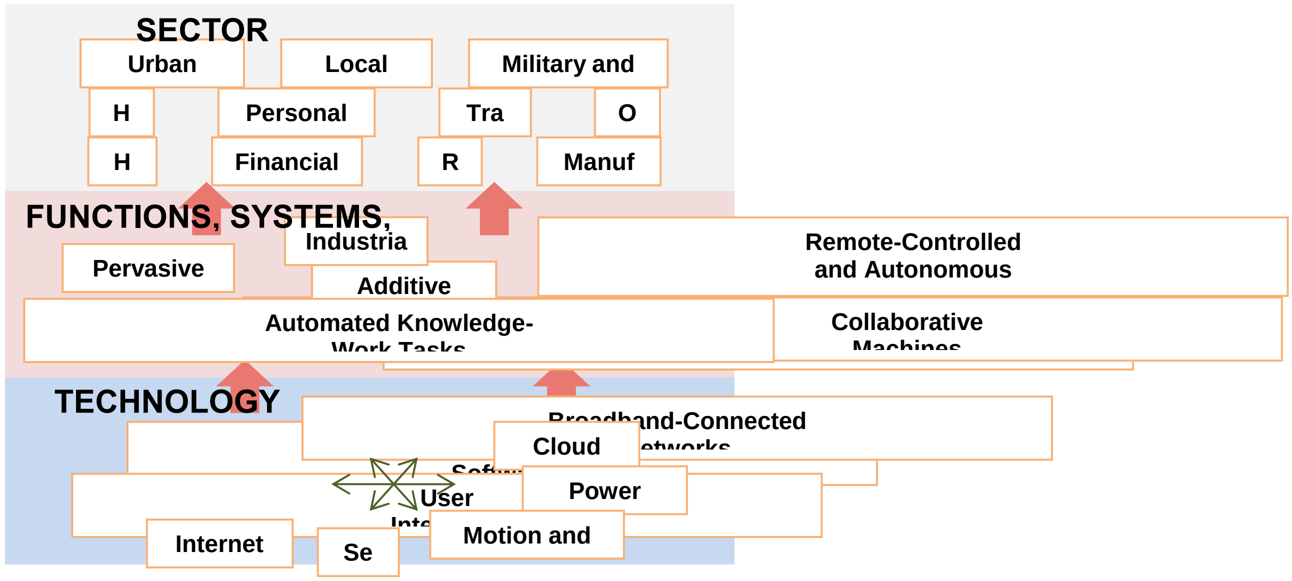
To develop insight into technology flows and technology's role in shaping social, economic, political, and ecological flows around the world in the next 20 years, it is necessary to develop an integrated international perspective on technology flows and then narrow the focus to specific technologies, in this case advanced-automation technologies, and their influence on economic and social conditions in two geographies, in this case Europe and the United States.

Figure 2. Europe/North America Game-Changer: Advanced Automation



Leveraging SBI's ongoing business-research programs Scan™ and Explorer, we identified the technology building blocks that will drive advanced automation and new automation functions, systems, and capabilities in the next 20 years. We then analyzed the impacts of advanced automation on three key economic sectors for Europe and North America, healthcare, financial services, and retail. Those impacts will likely be very extensive, based on what we're seeing today being commercialized, the resources being invested in new products and services, and market demand. This technology-economic system of advanced automation is reflected in the map below.

Figure 3. Advanced Automation Technology Map



Advances in automation technologies will create new human and machine functions and capabilities that will spur productivity, stimulate new markets, and lead to enhanced decision-making, while at the same time forcing change to existing industrial processes, the elimination of many products and services, and the development of new personal routines and connections. Individually, these technology advances are important and interesting, but together they provide the potential for a wide range of new automation functions, capabilities, products, and services that could disrupt every aspect of our lives.

The first key building block for advances in automation is **artificial-intelligence (AI) software.** In pure number crunching and reaction time, machines can already outperform people, and since machine learning will get better the more data it has, and with data growing very rapidly, the prospect is increasing that machines could quickly becoming smarter than humans—Watson was only the beginning.

The extent of machines being able to recognize the content of images and audio and interpreting the meaning of text will depend on advances in pattern-recognition methods. Software today has significant but still limited ability to detect high-level attributes (feature extraction) of sounds, images, and other inputs and to sort inputs into categories (classification), but the potential exists for dramatic improvements in recognition technology, enabling automated analysis of security-camera images, automated generation of machine-readable data from natural-language text, and pattern recognition using fusion of multiple data sources (such as detecting user intent via fusion of sounds, images, and explicit inputs). The goal of learning to become autonomous has inspired large-scale research projects such as the European Commission–funded RobotCub and DARPA's CALO.

Another area of AI that is rapidly evolving is agent software. Agent software can play a humanlike role, or act on behalf of a human user, or substitute for a human user, or act autonomously without human intervention, or present a convincing simulation of a human.

Some researchers believe that rapid increases in computer technology could enable artificial neural networks to achieve the scope and scale of the human visual cortex by 2020. While "humanlike" intelligence is a vague and perhaps unachievable goal, the emergence of machines with considerable insight and capabilities—in many domains, far beyond the capabilities of people—seems plausible.

As an increasing number of devices add data connections and a growing reliance on **mobile and broadband networks** for entertainment content, the capacities of fixed and mobile data networks are being continually stretched, stimulating technology innovation and the development of new business models throughout the world. At the same time, **cloud services** are now accessible and simple to use. The public cloud market—services like Amazon Web Services, Rackspace, and VMWare—is growing at a rate of almost 20% per year and surpassed the $100 billion mark in 2012. Cloud services' multiplatform accessibility gives users a preview of a device-agnostic, synchronization- and version-control-free future, in which their data and services would be available to access and edit any time they have access to the Internet.

Sensors are another technology building block for advances in automation. Sensors for automation applications fall into two distinct categories: internal sensing (monitoring a machine's position and movement while performing a task such as materials handling) and external sensing (monitoring a machine's external environment). Improvements in internal sensing are enabling industrial robots to migrate from their traditional manufacturing role to roles in other industry sectors, while improvements in external sensing are enabling mobile robots to perform highly useful tasks autonomously in many environments. Developments in micromachining and nanotechnology are also leading to smaller and more sensitive sensors.

Other "hard" technology areas that will be important in developing humanlike movement for machines will be **power, motion, and manipulation technologies**. Power technologies are key for nonindustrial, mobile robots. While major breakthroughs are not expected in power technologies (battery and motor technologies or fuel-powered engines), widespread development efforts should result in important advances in rechargeable batteries, charging stations, fuel cells, etc. that will support the many new automation applications. For motion, a wide range of mobile robot options are being developed, from simple wheeled robots to advanced bipedal humanoid robots, while advances in sensors and actuators are enabling increasing degrees of dexterity by machines in handling objects. An exciting area of innovation is using artificial muscles for actuation.

The evolving **internet of things** promises to add new functionalities to an increasingly connected globe. Tagging systems like RFID will give physical objects a persistent digital identity that can appear in a globally accessible registry; they will support an array of integrated tracking services; and they will enable both machine-to-person and machine-to-machine communications. At shipping ports, containers could report their contents to heavy equipment, which could route goods to trucks automatically; at distribution points, pallets and forklifts could similarly communicate and route goods that arrive in stores largely untouched by human hands.

The final important building block for advances in automation is the **user interfaces** that mediate people's relationships with computers, cars, entertainment electronics, office automation, technology in public space, and handheld devices. The advent of natural-language speech interfaces such as Apple's Siri and IBM's Watson suggests people will engage in increasingly natural modes of interaction with machines; some developers even envision hands-free, motionless, silent sensing of a human operator's intentions and thoughts. If successful, research for neural and bioelectric user interfaces could apply to robot control. Honda has already demonstrated limited control of its Asimo robot via a wearable bioelectric-sensor helmet.

New Automation Functions, Systems, and Capabilities

When integrated together, these building blocks create a wide range of new automation functions, systems, and capabilities that will be used by government, industry, and individuals in transformative ways. There's simply no end to the new, and often disruptive, applications of these new ways of doing things. The important new functions, systems, and capabilities include:

Telepresence and teleoperation

Teleoperation refers to technologies that allow users to have control over distant events, In contrast to teleoperation alone—which includes simply issuing commands that a distant machine fulfills—telepresence entails intimate knowledge of the distant environment and provides users the ability to act at a distance despite major obstacles, including environments that are too hazardous for people and the obstacles faced by people who have impaired use of their limbs. When a doctor-controlled robot performs surgery today, the doctor is normally in the same room. But researchers expect that future robotic surgery will occur via wide-area networks.

Industrial Robots

Advanced automation will enable industrial robots to move into many jobs that currently require skilled labor and eliminate the need for human labor entirely in some manufacturing environments, including many service roles—such as maintenance, logistics, inspection, and cleaning—in industrial environments.

Additive manufacturing (3D printing)

Additive machines provide a new automation capability for the future that many companies and individuals will find uses for.

Nonindustrial or personal robots

A nonindustrial robot is a machine that users can program to perform manipulative and in some cases locomotive tasks under automatic control. Nonindustrial robots already patrol hospital corridors and distribute supplies, while the U.S. military has thousands of nonindustrial robots operating on battlefields. New generations of personal robots for an extremely wide variety of service-sector applications—including cleaning, healthcare, public relations, and maintenance applications—are under development.

Remote-controlled and autonomous vehicles (aka unmanned vehicles)

A remote-controlled vehicle refers either to remote-operated versions of traditional land, sea, and air vehicles, or to specialized mobile tele-robotic platforms like bomb-disposal robots and tethered submersibles. Autonomous vehicles are mobile platforms that can operate without any direct human control, and incorporate sensors and control software to orient the vehicle and avoid obstacles.

Collaborative Machines

The development of machines that can work in collaboration with humans and with other machines will be key for being highly efficient at many tasks. Robot swarms, in which groups of robots are controllable through various algorithms, will be able to execute complex behavior in harsh environments, while collaboration between a machine and a human can greatly enhance rather than replace the human because developing a machine that relies mainly on human intelligence is far more practical than developing strong artificial intelligence.

Pervasive computing

Increasingly, individuals are using information technology and networks to sense and understand variables that relate to that user's needs to which the system can respond. In a most basic example, consider a thermostat that recognizes when the temperature in a room drops below a preset level determined by the user and responds by turning on the heat. In the future, more advanced pervasive-computing environments that are always on, always available, unobtrusive, and self-adjusting to meet people's wants and needs, will shift dramatically the way that people relate to their surroundings and human notions of privacy, safety, and perhaps even liberty.

Automated knowledge-work tasks

The advances in machine learning, big data analytics, pattern recognition, and user interfaces are facilitating the automation of more and more tasks performed by knowledge workers. "E-discovery" software can already analyze legal documents much more quickly than can human labor and for lower cost. In time, machine-learning systems will get better, gaining powerful intelligence from internet and sensor data.

Key Sector Impacts of Automation

The widespread new functions and capabilities from this automation ecosystem will be particularly impactful on Europe and North America and the many connections between the two because they have the industrial and societal needs for change, the means for investing in the new equipment, systems, functions, and capabilities, and the leaders able to take the risks. We've selected three economic sectors to focus on to understand the possible outcomes from advanced automation on Europe and North America: healthcare, financial services, and retail. In determining these possible outcomes, we took into account the many business, social, environmental, and governmental factors that determine what gets commercialized, when, and by whom. A final caveat, these projections are very uncertain and not based on detailed industry, sector, company, or product analyses.

Case Study I: Automation in Health

This section reviews the implications for healthcare automation from three standpoints: the automation of diagnosis and treatment through bioanalytics, automated 3D manufacturing of body parts and tissue, and the automation of care and logistics.

Current Situation

Automation has been an important enabler for accurate, fast and inexpensive testing and measurement in support of healthcare diagnosis and treatment—automated functionalities include sample preparation, fluid dispensing, sensing and detection and pattern-recognition software. Bioanalytical systems can measure the presence of specific molecular components, the existence of particular DNA sequences or the presence of antibodies that indicate infection. With new types of gene and protein microarrays and high-throughput screening platforms, researchers and clinicians have tools that allow massive parallelism in experimentation and testing, providing new leads for drug discovery and clinical diagnostics. The early focus of genetic platforms has been in the diagnosis and treatment of infectious diseases, but personalizing medical treatment using genotype data (pharmacogenomics) is growing in importance as a way of improving healthcare outcomes and avoiding adverse drug responses. Example diagnostics include testing to determine the correct Warfarin dosage (an anticoagulant) or in support of breast cancer treatment.

Additive manufacturing or 3D printing has the potential to create customized body parts. Such machines use computer-aided design (CAD) and a computer-guided laser, extruder, or printer head to construct an object one layer at a time and can generate geometrically complex objects. 3D printing is already in use to make models or temporary objects from plastics in sectors such as consumer products, automotive and aerospace, but it is particularly suited to applications requiring the rapid production of unique or personalized parts. A combination of 3D imaging technology, real-time finite element analysis and computer-guided 3D printing can automate the fabrication of highly customized prosthetics and implants applicable to the medical and dental fields. The field is still in its infancy, and is currently focused on structural components using advanced polymer composites.

Automation also supports clinical and non-clinical care and logistics on the healthcare "shop floor." Today, the functionalities are normally discrete and mostly within structured settings. Simple patient lifts may help within the hospital or at home. Within the field of telemedicine, visual monitoring systems and wireless devices may alert caregivers to patient falls in care centers or at home. In logistics, vacuum-tube pharmacy automation systems are now commonplace and guided vehicles from U.S. and European companies can deliver drugs, linen, food and other supplies. Some autonomous robots with laser navigation and wireless connectivity operate on non-predefined routes and can navigate hospital elevators to carry out deliveries. Today, around two thousand high-value surgical robots operate worldwide carrying out minimally invasive surgery for procedures including prostate removal and hysterectomies; other robots provide automated steering of intravascular catheters.

Potential Outcomes in 2030

Increases in longevity in the United States and Europe, advances in healthcare treatments and the economic strain due to declining support ratios will put a strain on healthcare systems in many countries forcing healthcare and elder-age care sectors to improve efficiency. In Europe, the United States (and Japan), the availability of professional caregivers for elder-age care is likely to become problematic.

Twenty years ago, biochip-based genomic testing did not exist and researchers had not mapped the human genome. Today, a person can obtain an entire map of their human genome for around $1000 and by 2030 human genome mapping may be a routine procedure after birth. By 2030, human genomes from a variety of populations will be stored in the cloud, just as Amazon began hosting the National Institutes of Health 1,000 Genomes Project in 2012. Advances in pharmacogenomics will lead to dramatic increases in the personalization of medical treatment, with more of the value likely to move toward cloud-based computational analytics and diagnostics services, including by non-typical healthcare providers. With early baby boomers reaching 84 in 2030, improving patient outcomes due to more effective personalized therapies has the potential to reduce healthcare provider expenditures by reducing the need for expensive in-patient care. Equally, a danger exists that patients armed with personal genomic information will expect too much from national healthcare systems and begin shopping around for new diagnoses and treatments.

Scientists are already working on a number of approaches for 3D tissue printing for creating cartilage, skin, bone, blood vessels, or for complex mechanical components such as aortic heart valves. By 2030, customized 3D printing could be an established method within the medical and dental device and implant communities, particularly for plastic and biocompatible polymers. Given the regulatory approvals necessary, development in 3D tissue printing will be more limited, but we could see applications in organ repair or tissue implants as part of wider trends in regenerative medicine. In May 2013, doctors in the United States used a 3D-printed tracheal-support implant—using the biopolymer polycaprolactone—to save the life of a young baby. The child was suffering from a severe form of tracheobronchomalacia, in which the trachea collapses because of the lack of supporting cartilage. The biopolymer implant guides the growth of natural cartilage and will gradually dissolve as the child grows.

Autonomous robots are emerging that provide healthcare concierge and registration services, enable patients to communicate with relatives or be the “eyes and ears” of remote doctors, together with onsite nursing staff. By 2030, this new level of automation in unstructured settings could extend to closer physical interaction with patients in hospitals (such as patient lifting, lavatory help), or in the home to support elder care. By 2030, robot hardware is likely to become more standardized, even commoditized, and value will move to robot services, with monitoring and intelligent control of robot swarms moving to the cloud. Multifunctional robots armed with germ sensors and UV beams could kill harmful hospital bacteria, viruses, fungi or pathogens, or equally provide patients with superior non-clinical services that are often the main reason for hospital choice, particularly in the United States.

Case Study II: Automation in Financial Services

Current Situation

Automation of financial services has been ongoing for many years. Automated teller machines first arrived over 40 years ago. Retail banks further automated their operations through call centers and websites. Today, voice recognition systems fully automate much telephone banking, mobile apps make automated financial services available anywhere, and even the bank branches that remain support many automated machines and few bank tellers.

Automation in financial services goes beyond transactional tasks. Consumer finance was among the first sectors to adopt advanced pattern recognition software such as neural networks to automate complex analytical and knowledge-based tasks. For example, HNC Software started selling the neural-network-based Falcon fraud detection software during the 1990s and this software (now marketed by FICO) is now used by 17 of the top 20 credit card issuers worldwide to spot potential fraud.

Automation in investment banking is arguably even more advanced than in retail banking. Over the last twenty years, automation of financial exchanges and back office functions has transformed financial markets. Open-outcry trading (or pit trading) featuring traders in brightly colored jackets issuing hand signals is now a largely a thing of the past and traders now sit in front of banks of computer screens, pressing buttons and relying on automated electronic trading systems to make and fulfill trades.

In recent years, automation software has even started to automate traders themselves. Over the last decade, high-speed financial trading emerged has emerged as an entire new sub-industry with specialist automated-trading firms competing with one another to analyze statistical patterns and make trades in fractions of seconds. Such automated trading has changed markets. In his book *Dark Pools* Scott Patterson reports that some estimates put the average holding period for a stock at four years in 1945, eight months in 2000, two months in 2008, and 22 seconds in 2011.[3]

Automated trading has had some unpredictable effects on markets. In 2010, a “flash crash” occurred when competing algorithms briefly drove down the New York Stock Exchange by around 9%. In April 2013, a news outlet reported a fake Twitter posting about terrorism in the United States and again algorithms caused a short-lived market tumble.

Because of these and other issues regulators and market operators are looking more closely at high-speed trading. For example, in the United States, the New York Stock Exchange has implemented a system limiting sudden price swings. Alongside this increased scrutiny many

[3] Scott Patterson, *Dark Pools*. New York: Crown Business, 2012.

high-speed trading firms are struggling because increased competition and market changes have driven down profits.

Despite these challenges advocates of automated trading are still trying to develop new systems and strategies, particularly with machine learning algorithms that learn from vast volumes of data inside and outside the financial system to infer information pertinent to trading. For example, Cerebellum Capital's genetic algorithm software analyzes conventional financial data alongside varied Internet data such as restaurant reservations to evolve new trading algorithms. The Cerebellum ATM Fund returned around 7% a year between 2009 and 2011, according to Scott Patterson.

Potential Outcomes in 2030

Long-term trends support increased automation in financial services. Over the last few decades, financial institutions have been among the most enthusiastic adopters of automation technologies and that they would break this pattern over the next two decades seems highly unlikely.

Although automation of transactional finance will have increased by 2030 (perhaps almost fully automating the sector), the bigger change from today will be the increased automation of knowledge work. By 2030, automated systems capable of spotting complex financial patterns will be far more advanced than those of today and routinely outperform human workers. This change is likely because of the combination of increasing computer power, proliferating data, and cultivation of machine-learning algorithms that perform better the more data they have access to (note that in 2012 IBM suggested that creation of 90% of the world's data took place in the prior two years).

Although automation will impact all areas of finance, automated trading perhaps provides the best illustration of the potential impact of new machine learning systems. For example, by 2030, instead of simply carrying out short-term trades, software may be running large and complex long-term trading operations that outperform human-managed investments. Mainstream investment banks are likely to be running such software, not just specialist funds, though they may compete against offshoots of major software firms as well as other banks. With increased automation, human traders may be relegated to a few niche markets, as open-outcry traders are today. Inside financial institutions, human managers and technicians may be supporting and maintaining increasingly autonomous trading software.

In 2030, trading software is likely to be analyzing vast quantities of historical and real-time data on financial systems and on the Internet. This Internet data will be far richer than today's data because developments such as wearable computing and the Internet of Things will yield vast quantities of new data about the activities and conditions of objects, people, businesses, and environments. As well as learning from this raw data, trading algorithms will benefit from an ecosystem of automated software services that pre-process information. Already, services such as MarketBrief automatically create financial news stories in machine-readable formats.

Because many different firms will operate competing automated trading software and because this software will interact with a vast and complex ecosystem of supporting data and services, the complexity of the financial markets in 2030 may be far greater than the complexity of markets today. To keep pace, regulators may themselves turn to automated approaches. Cornell University professors Maureen O'Hara and David Easley have suggested that automated software could monitor markets for reckless behavior in real time.[4]

Case Study III: Automation in Retail

Current Situation

The retail sector has seen massive changes in the past couple of decades. In the United States, retail employment tripled between 1940 and 2000, and during that time emplyed more people than the health-care and construction sector combined. Since 1990, United States' retail employment has slowed, and the sector now employs fewer people than it did in 1999. This reduction is due to a number of factors, including the economic climate, consolidation, and automation of retail processes. Thirty years ago, people went shopping. Today, automation means that stores effectively go to people. Where once people looked to shop assistants for advice, now consumers turn to retail websites, forums, and online reviews.

Since its emergence, online retail has encroached on physical, or brick-and-mortar, retail. Online retail has become a veritable competitor to real-world retail operations, with serious implications for revenue generation, consumer expectations, and even the design of urban environments. Online retailers such as Amazon can record up to as three times as many sales per full-time employee, in comparison to the retail average. According to Forrester Research, e-commerce already accounts for around 8% of all retail sales in the United States. E-commerce has recently been even more successful in Europe, where the market is now worth in excess of $300 billion per year. Major players such as Amazon (United States) and Otto (Germany) are already household names in many countries. According to Ron Josey, an internet analyst with JMP Securities, shoppers also use the Web to research over 50% of the products that they eventually buy in person. In countries like the United Kingdom, buying groceries online has become commonplace.[5]

Automation has also changed the way physical stores operate. Self-checkouts have started replacing some traditional checkouts. According to research RBR (United Kingdom), around 170,000 self-checkout terminals were already in operation across the world through 2012. Companies such as UK supermarket Tesco have already installed portable scanning equipment that customers take with them around the store.

Automation is already starting to change the way we pay for products and services. For example, consumers can already purchase items at Home Depot (Atlanta, Georgia) using only their mobile-phone number and personal identification number. Start-up Square has also developed a unique form of cashless payment that allows customers to initiate payment through their smart

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[4] See http://engineering.nyu.edu/press-release/2013/04/23/finance-industry-explore-risks-and-rewards-big-data

[5] See http://www.localmedia.org/wp-content/uploads/2014/07/01_830_NativeAdvertisingOutlookfor2014andBeyond_Josey-Compatibility-Mode.pdf.

phones, without physically swiping a credit card or signing receipts. The app also organizes rewards points, reviews of companies and stores, and information about past purchases.

Naturally, automation software has also enabled retailers to know more about their customers. Physical retail stores have used credit-card and loyalty-card data to gather consumer information for some time. In recent years, social networks have augmented loyalty-card data. Now, in conjunction with closed-circuit cameras, customer-tracking software records and analyzes shopper behavior. For example, Immersive Labs (New York, New York) has developed video-analysis software that can extract the age and gender of a person in a video feed via face-recognition technology. And Realeyes (London, England) developed a system that can track the position of various facial features—including eyebrows, nostrils, and mouth—and then infer mood from changes in the alignment of those facial features.

Potential Outcomes in 2030

Long-term trends support increasing automation in retail In addition to e-commerce, recent years have seen the emergence of m-commerce—purchases of products and services using smart phones. By 2030, almost every kind of technology needed to support decision-making could become automated. Indeed, advanced software may even automate the decision making process accurately enough for consumers to have confidence in it. E-commerce—and its sibling m-commerce—will quite probably be responsible for a large percentage of total retail sales. Social networks may function as a portal through which those transactions occur. Already, Commonwealth Bank has announced that its customers will soon be able to transfer funds between accounts and receive money electronically through an application on Facebook's social network. By 2030, such activity could become common.

Further automation in physical retail will occur. Market-research company RBR (United Kingdom) forecasts that the global installed base of self-checkout terminals will reach 320,000 by 2018.[6] By 2030, these systems perhaps will be omnipresent. By 2030, automation will make any retail experience highly personalized. Safeway, a large chain of grocery stores in the United States, has already developed an automated personalized price system for its customers. Customers for specific products will pay a price that reflects that customers' past purchasing history. Catalina, a marketing company, has already worked with Stop & Shop's Ahold division to send coupons for specific products to customers via their smart phones while the customers are actually in the store. By 2030, a surprisingly high percentage of retail transactions could become highly personalized.

Other areas of change could see further automation. The product delivery and logistics side of retail could also change considerably by 2030. Manufacturers are already developing autonomous vehicles—for use not only on the ground but also in the air. Event planners and restaurants already intend to use unmanned drones—small eight-propeller helicopters—to deliver beer to crowds at festivals, or perhaps pizzas to customers. Although currently a publicity stunt, the concept is simple: Customers use a smart phone app to order, send payment, and provide geolocation information; the drone returns with the product. Perhaps most significantly,

[6] See http://www.rbrlondon.com/retail/RBR_SCO_PR_2013.pdf.

major e-retailer Amazon announced its *Prime Air* concept in late 2013, an R&D project to investigate the use of octocopter delivery drones. By 2030, ground and air autonomous-delivery systems may well be technically and economically possible.

Buying is another important function within retail that could change. While professional buyers currently help retailers find appropriate product lines to sell, and negotiate with suppliers, by 2030 this side of the retail business could see significant automation.

Implications for Europe and North America

Advanced automation will have significant effects on the economies and societies of Europe and North America because Europe and North America both need the new economy/work solutions enabled by automation to remain competitive with emerging-economy solutions and because the citizens of Europe and North America, who have the means, and freedom, to change their lives, will be attracted by the many benefits provided by new automation. But these changes will have both positive and negative impacts on developed-world economies as private-sector competitive environments adjust; as governments try to implement new information management, policy setting, regulatory, and public safety functions and capabilities; and as people adjust to new personal environments. With their high-skilled labor forces, diversity of technical and engineering talent available in their regions, and demanding customers, the Europe and North America are well positioned to lead the development of automation technologies and systems and supply the companies that will serve the new markets. On the other hand, the European and North American regions are already invested in current ways of doing things, and changes to meet future societal needs for connectedness and to remain industrially competitive will be difficult because they will require almost everyone to acquire new skills and live their lives differently. There will be many costs in making these changes.

Figure 4. Potential European and North American Flow Impacts from Advances in Automation

Economic Sector	**European and North American Flow Impacts**
Healthcare	The development of healthcare automation in the next 20 years will stimulate the movement of capital, to invest in new companies, the flow of new products and services, and of expertise and intellectual property. As such, the major flows impacts from healthcare automation will be functional global economic flows and global technology flows. Flow circuits will

	primarily involve the United States and Europe, but developing countries could play a role in custom manufacturing (China) or software and services (India). Global social flows will also be affected by healthcare automation, but the impacts will vary: • Healthcare automation will drive greater personalization or choice for individuals, but potentially at the expense of even greater demand on public healthcare systems • Some negative impacts on labor are likely as automation is used to improve operational efficiency and reduce labor requirements. • Some professional groups in developed countries may be adversely affected as technology reduces the cost of customization and creates greater internationalization of flows of expertise. Automation in diagnostics has primarily involved flows of investment capital—to fund startups or make acquisitions mainly in the United States—of capital equipment and of ideas. Diagnosis and treatment has remained mostly localized, but the internationalization of personal genome mapping is now but a DNA test kit and email away. Cloud-based analytical services in areas such as pharmacogenomics could see the circuits, flows and value moving to international centers of computational excellence, away from traditional national healthcare providers, although regulatory influences may slow such a transition. Mass customization via additive manufacturing is also part of the trend in the personalization of health and can alter supply chains and flows by breaking down barriers between the manufacturer and final customer. In healthcare, a 3D-printed medical parts supplier and healthcare provider could be co-located, but equally patients armed with electronic records, including 3D imaging data, might order some body parts globally from 3D manufacturing centers of excellence. New more complex circuits and flows could result if patient, medical parts supplier and service provider are all in different regions, with implications for medical tourism. Overall, such healthcare flow circuits could operate with reduced human intervention thereby lowering cost and downward cost pressure is likely on some professions that have benefitted from the high value of medical customization. In contrast, healthcare systems should benefit from lower costs.

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	Healthcare-service robots will replace, or augment, low- and medium-skill human labor and the provision of such services could, at least in part, be offshore. For example, robot monitoring or robot remote control services could transfer to low-cost computer literate regions such as India. In regions in which this human labor is in short supply (such as Japan) or where immigration may be contentious, governments are likely to welcome such automation. However, in terms of social flows, workers in some sectors may find their employment positions more precarious. High-end surgical robotics and telemedicine have the potential to move the provision of some medical services to locations where physicians are either better-trained or lower cost. This potential for the internationalization of flows around surgical care is likely to face challenges from national regulatory bodies due to privacy and security concerns and from among local professional bodies.
Financial Services	The major EU-U.S. flow impacts from future automation in financial services will include the increases in capital flows within and between regions because of better products and services from financial services companies located in the regions, the increased use of information-technology services by financial services institutions, the delivery of services by those institutions to customers, and the movement of talent, expertise, and intellectual property among regions to fill the changing needs. Employment in financial sectors and across consumer finance will be negatively impacted. By 2030 financial markets are likely to be very different from today, due to increased automation and a furthering flattening of the global financial system. Multinationals and governments from Europe and North America will both likely continue to be major participants in the global system. Singapore and Hong Kong may increase in importance due to better than average mathematical skills in those regions, and the increasing reliance on mathematical skills in finance. Also foreign direct investments in Europe and the United States probably won't grow, as they will in developing countries. In themselves, European financial markets could remain weak for most of the period. European governments will likely be unwilling to let national private-sector institutions fail, and in the midst of voluminous data and automated financial-transaction capabilities, government regulatory agencies will struggle to develop and implement new laws and regulations to fit the new high-tech environments.

	From the perspective of Tomas Ries,[7] the major flow impacts from future automation in financial services will be on the functional global economic flows and global technology flows. Global social flows will also be affected. In particular, increasing automation implies that technology flows (and the accompanying economic flows) will be increasingly independent of people. Potentially, automation software could deal with and create complete flow circuits without human intervention. Today, human fund managers are arguably still the "directing factor" but potential exists for automated software to manage complex portfolios of trading algorithms, taking the human out of this flow circuit altogether. If the next wave of financial trading automation is successful, then a faster and more efficient technology flow will support greater economic flow. But this could be an environment of winners and losers. Increased automated trading implies fewer human traders (along with their support staff) and trading profits may be shared amongst fewer individuals. At least in theory, increasing automation should drive down fees for investors, making investing more attractive for a wider group of people than it is today. The flash crash of 2010 and the hash crash of 2013 have demonstrated than highly automated financial systems can be fragile and unpredictable. As complexity increases, a key risk is that regulators fail to stay ahead of technology developments and that automation leads to greater instability in the global financial system. Rogue software (planted by terrorists or other groups) is another risk. For example, rogue algorithms could attempt to deliberately cause market crashes. The technology to support automation in finance will be primarily operational rather than capital expenditure, due to the increasing reliance on cloud services rather than in-house hardware. The flows of this expenditure will include those from the United States to Europe (perhaps particularly to financial centers) but primarily from Europe to the United States. Information flows all around the world will increase as automated systems track myriad Internet data. Sometimes this data will be licensed, increasing financial flows, though often the data will be freely available. Changes in the financial sector are likely to create increased

[7] See his chapter in this volume.

	demand for technical staff, particularly those that can combine machine-learning expertise with an understanding of the finance sector. Expertise and intellectual property flows are likely to be fairly fluid between Europe's, Asia's, and the United States' main financial centers. Countries whose students perform well in numerate subjects, notably China, Hong Kong, Singapore, and South Korea, are likely to make increasing inroads into the new, more mathematical financial sector. Financial sectors in Hong Kong and Singapore are likely to grow in importance. Whether new financial sectors will emerge in China, South Korea or elsewhere or whether students will migrate to existing financial centers is uncertain. Employment in consumer finance is likely to decline across the world as automation of transactional and knowledge-based work in the sector gathers pace. Financial centers in Europe, Asia, and the United States may also see reduced demand for traders and related support staff as automated traded operations become commonplace. It's uncertain how the need for navigation or auxiliary services might change, and possibly increase.
Retail	The flows that new automation in retail will stimulate are likely to be extremely wide in scope. In particular, the flow of information will increase as automated retail systems track and analyze consumers' data. Information will flow between retailers, payment-systems companies, cloud-computing providers, and social networking services. Many companies developing some of the novel enabling technologies, software, apps, and digital infrastructure, for use in retail, are based in the United States. The activities of large players such as Google, Facebook, Amazon—and perhaps new service-providers that emerge in the interim—will increasingly overlap with any retail transaction. If automation approaches prove successful in retail, economic and social change could result. Retail flow circuits could operate with minimal human intervention, potentially driving down operating costs and increasing retailers' margins. Economic flows would increase. Currently, a large number of people are employed in the retail sector—not only in customer-facing roles, but also in areas such as management and logistics. Potential exists for significant change: For example, future retail warehouses could be

	controlled entirely automatically—using management software and robotics. In other words, humans could leave this part of the retail flow circuit completely. Social change could also occur: Globally, the nature of employment in the retail sector in the will be affected; fewer retail workers (in particular, store assistants) will be needed at showrooms and retail outlets. However, workers that do remain will likely be higher skilled than many of today's workers, with specialty knowledge. Changes in the retail sector are likely to create opportunities for technical personnel. Expertise and intellectual-property flows are likely to prove fluid, involving players both in Europe and the United States.

Conclusion

In summary, the flow of ideas, knowledge, and intellectual property related to technical advancements and innovations will not only increase in volume and speed in the next 20 years, it will be increasingly dispersed in both developed and developing countries. With a global economic system increasingly shaped by emerging markets, the sources of technology will be increasingly Asian.

Stimulated by widespread technological innovation in both information and mechanical/electrical arenas, advanced automation will disrupt many industries, government services, and elements of our social lives in the next 20 years. To understand the potential impacts, we examined three industrial sectors, healthcare, financial services and retail, and considered the flow implications for Europe and North America.

Advances in many automation areas, particularly those related to machine learning and decision making, will probably be applied first in the financial services industry, and since Europe and North America institutions currently dominate this industry, they should be well positioned to implement the new advances first and take advantage of the value created. These effects will flow subsequently to China, and then the rest of the emerging economies. But the balance between labor expenditures and machine expenditures will continue to move toward the machine side.

Automation technology flows will have a very large impact on healthcare because of the urgent needs in developed countries for improved operational efficiency, lower cost, and reduced labor requirements. But we also see the demand for greater personalization or choice as another key factor in the increases in healthcare automation. Up to now, healthcare economic systems have been mostly national with small cross-border flows. But automation technology could change that in a major way. High-end surgical robotics and telemedicine have the potential to stimulate all sorts of international flows, including the provision of medical services by locations where physicians are either better-trained or lower cost to anywhere in the world, the movement of patients to large-volume, high-tech surgical centers, and the export of high-tech hardware developed and developing countries. This potential for the internationalization of surgical care is likely to face challenges from national regulatory bodies due to privacy and security concerns and from among local professional bodies.

Automation innovations in retail in response to market needs will be implemented rapidly in both Europe and North America. The retail situations in Europe and North America are quite similar vis-à-vis the challenges retail companies face and the buying behaviors of their populations. As a result, the flow of ideas, products, and services in retail between the continents should be heavy.

Notwithstanding the increased social and economic flows the two regions will realize from more automation, the automation of work and new ways in which organizations use human labor will have enormous social and economic implications, perhaps particularly in areas like retail and lower-level healthcare services. Labor employment could generally decline as many labor categories and positions will be eliminated, while wages of lower-level service workers may be stagnant for many years. At the same time, there will be some potential worker shortages in some areas, like nursing. A complicating factor could be that some jobs associated with automation would be more mobile than those they replace. In response a major flow we might see could be in education and training services to fill the new needs for skills, expertise, and adjusting to new work environments.

Future workplace automation and the new machines that can process the vast new quantities of data will likely alter significantly the costs of producing the goods and services demanded around the world and thus how businesses are organized and operate. While advanced-automation changes will stimulate increased demand for products and services because of lower costs, and thus overall prosperity, they will require new business models and connections among individuals and between individuals and firms and be disruptive for everyone.