HOW ROBOTICS WILL RESHAPE THE GLOBAL GEOPOLITICAL AND ECONOMIC LANDSCAPE

Introduction

While we are still in the early phases of the robotic revolution, now is the time for countries to prepare their economies and societies for the massive changes that lie ahead. Growing technological sophistication and rapidly dropping costs is leading to a vast increase in the number of jobs robots can perform in a highly efficient manner. This will not only lead to major increases in productivity, but also to the replacement of human workers in many sectors of the economy. The growing use of robots will also reduce the competitive advantage cheap labour has historically provided many developing countries. Another game changer is the vital contributions robots will make in helping aging societies get better control of their healthcare costs. The combined impact of all these changes not only puts into sharp focus the potential of robots to significantly improve the world's quality of life, it also brings to the forefront the unavoidable debate countries will have over how wealth and work should be redistributed on a societal level.

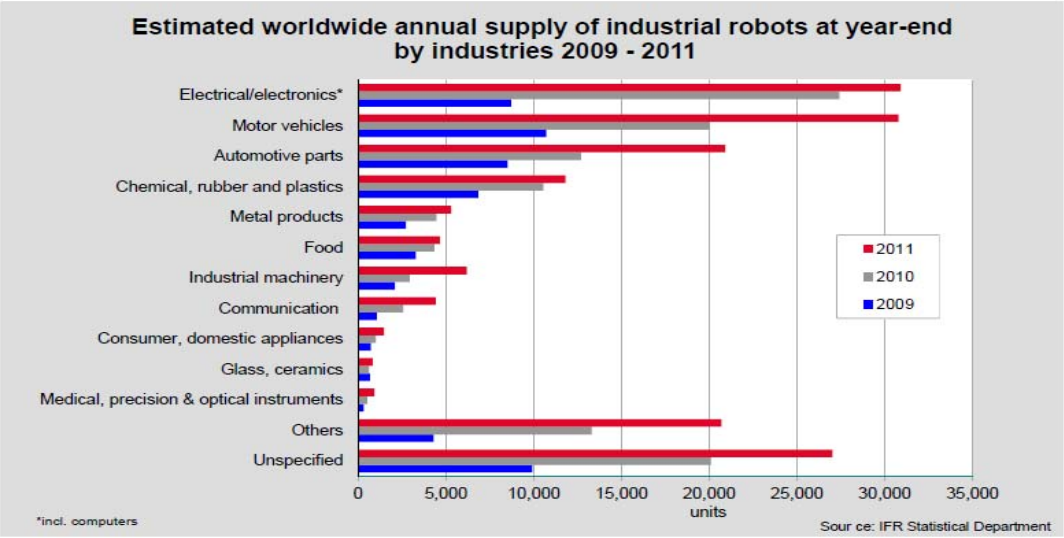
1) The growing use of robots in all spheres of human activity

Global demand for robots grew by an average of 9% annually between 2002 and 2012.[1] Going forward, Fredonia, a market research firm, estimates that global robot sales will increase by 11% per year through 2016.[2] In 2011, there were 1.15 million industrial robots in existence worldwide. It is projected their population will grow by another 30% by 2015.[3] **The chart below illustrates how many industrial robots have been purchased worldwide on an annual basis since 1994.**

Source: "World Robotics 2012 Industrial Robots," IFR, 2012

The following chart illustrates the pace at which various sectors have increased their use of robots over the last few years.

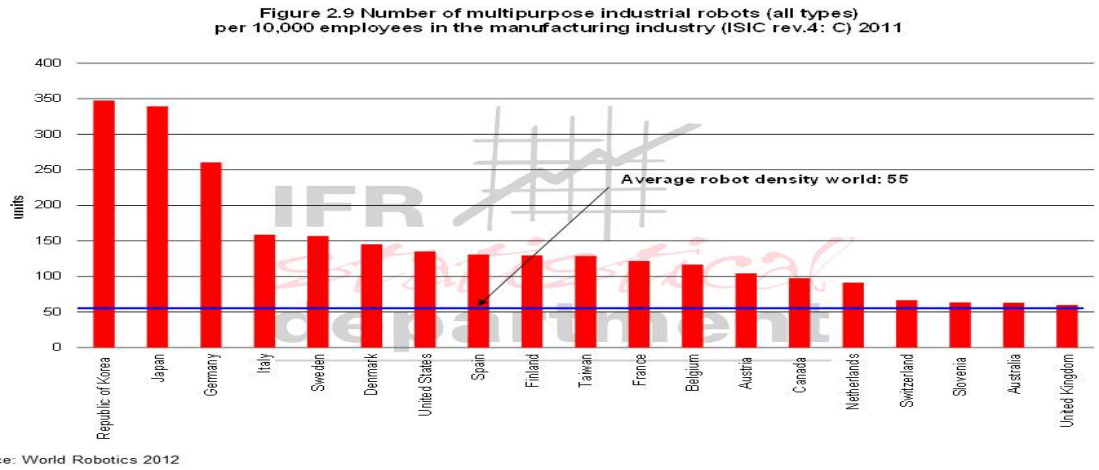
[1] "IFR: More than 160,000 industrial robots sold in 2012," International Federation of Robotics, February 2013
[2] "Cheaper Robots, Pricier Stocks," *Barron's*, Jan. 19, 2013
[3] "Humanoid Robots Changing Manufacturing In Japan," Nikkei, April 8, 2013



Source: "World Robotics 2012 Industrial Robots," IFR, 2012

Sales of industrial robots are projected to reach $41 billion in 2020,[4] up from $25 billion in 2011.[5] The chart below illustrates which countries have the most robots on a per employee basis in the industrial sector.

The countries with the most industrial robots per 10,000 employees (2011)



Sources: World Robotics 2012 & "These Are The Countries Where Robots Are Taking Over," Business Insider, Dec. 3, 2012

In aggregate terms, Japan has over 300,000 industrial robots, the most in the world, compared with 185, 000 for the United States.[6]

As for China, it has only 21 robots per 10,000 industrial workers compared with Germany's 251 and Japan's 339;[7] however, China has substantially increased its purchase of industrial robots over the last few years. In 2011, it purchased 22,577 industrial robots, up by 51% from the previous year. This made it the world's third

[4] "German Maker of Robots Gains as Chinese Wages Rise," *The New York Times*, April 13, 2012
[5] "Five inventions waiting to happen," *The Financial Times*, May 10, 2013
[6] "UK trails in march of the robots," *The Financial Times*, April 21, 2013
[7] "Robotics in Manufacturing in China," *CRI English* (Chinese daily), Nov. 10, 2012

largest buyer of industrial robots in 2011. **China has little choice but to continue increasing its purchases because the growing presence of robots in the developed world means that having low wage labour will constitute much less of a competitive advantage than it has in the past.** Indeed, the gap in manufacturing costs between China and the United States has already been narrowing. According to the Boston Consulting Group, the costs of manufacturing goods in China compared with the United States has gone from being on average 18% cheaper in 2003 to only 7% today.[8] The reasons for this include rising labour costs in China, cheaper U.S. energy and increasing automation of American factories. **The International Federation of Robotics predicts that China will become the world's largest purchaser of robots by 2014.**

Estimated number of annual shipments of multipurpose robots in selected countries

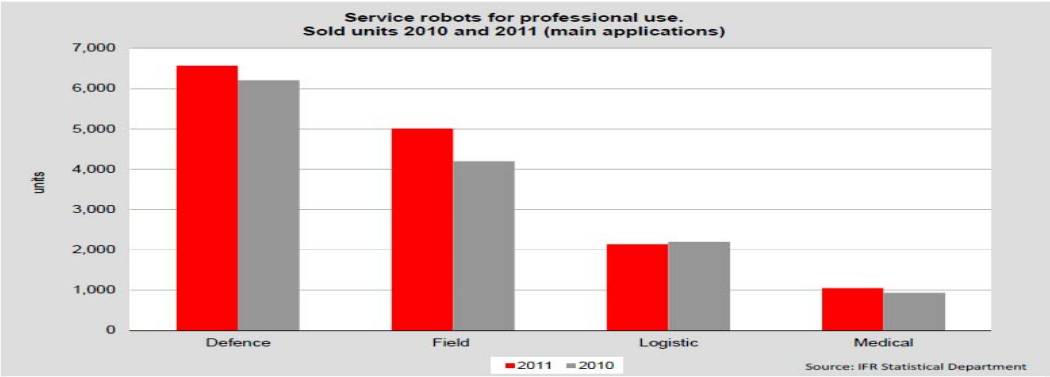
Country	2010	2011	2012*	2015*
America	**17,114**	**26,227**	**30,600**	**35,100**
North America (Canada, Mexico, USA)	16,356	24,341	28,000	31,000
Central and South America	758	1,886	2,600	4,100
Asia/Australia	**69,833**	**88,698**	**98,900**	**116,700**
China	**14,978**	**22,577**	**26,000**	**35,000**
India	776	1,547	2,000	3,500
Japan	21,903	27,894	31,000	35,000
Republic of Korea	23,508	25,536	26,800	25,000
Taiwan	3,290	3,688	4,400	5,500
Thailand	2,450	3,453	4,100	7,000
Other Asia/Australia	2,928	4,003	4,600	5,700
Europe	**20,483**	**43,826**	**44,100**	**47,200**
Czech Rep.	402	1,618	2,000	3,000
France	2,049	3,058	3,300	3,500
Germany	14,061	19,533	19,000	20,000
Italy	4,517	5,091	4,600	4,900
Spain	1,897	3,091	2,500	3,000
United Kingdom	878	1,514	2,000	2,200
other Europe	6,937	9,921	11,100	10,600
Africa	**259**	**323**	**350**	**500**
Total**	**120,585**	**166,028**	**180,950**	**207,500**

Sources: IFR, national robot associations.

Source: "World Robotics 2012 Industrial Robots," International Federation of Robots, 2012

Demand for robots is also growing strongly in other sectors

While the lion's share of robots are currently being utilized in the industrial sector, global demand for robots is growing strongly in such areas as defence, healthcare and agriculture (called 'Field' in chart below). The total number of professional service robots sold in 2011 was 16,408 units, up from 15,027 in 2010, an increase of 9%. In dollar terms, sales increased by 6% to US$ 3.6 billion. For the 2012-2015 period, it is projected another 93,800 (worth $16.3 billion) service robots will be purchased.[9]



Source: "World Robotics 2012 Industrial Robots," International Federation of Robots, 2012

Demand for robots that perform domestic tasks such as vacuuming and lawn mowing is also growing strongly. It projected that almost 11 million robots for personal use will be sold from 2012 to 2015.[10]

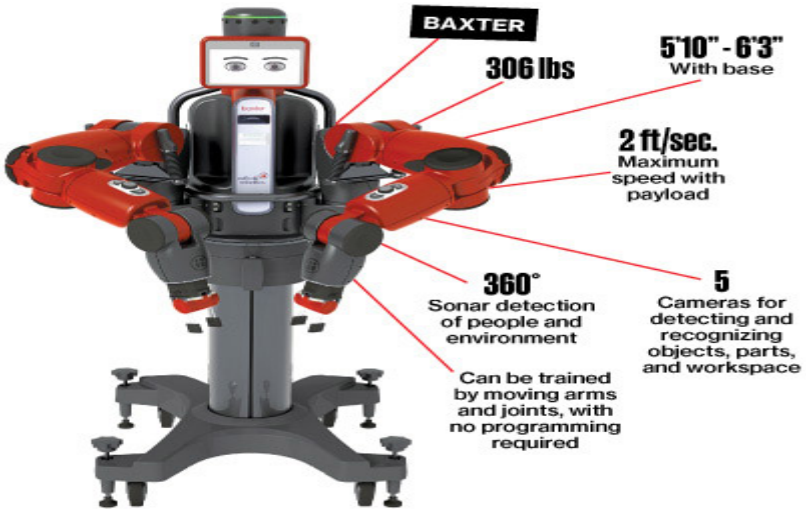
[8] "A Change in the Cost Equation," *The Wall Street Journal*, June 10, 2013
[9] "World Robotics 2012 Service Robots," International Federation of Robotics, 2012
[10] "World Robotics 2012 Service Robots," International Federation of Robotics, 2012

2) Increasingly sophisticated and less expensive, robots are replacing human labour at an accelerating pace

According to a study by consulting firm McKinsey, the cost of industrial robots has dropped by 40% to 50% relative to the price of labour in advanced countries since 1990.[11] The cost of an average assembly line industrial robot is in the $200,000 range.[12]

Jobs commonly performed by industrial robots include welding, painting, screwing devices together and transporting items. A new generation of robots are increasingly able to sense their surroundings via sight and sound systems, which allows them to distinguish between different components and even work alongside humans.

Rethink Robotics is an example of a company that is making increasingly intelligent robots at a relatively low cost. Its robot, which is called Baxter, can be taught to take certain items off a conveyor belt while working alongside people. The cost of Baxter is only $22,000.[13] At this price, it is the equivalent of $4 an hour for three years of eight-hour shifts.[14]



Source: "Smart Robot, With No Wage Demands," Businessweek, Sept. 18, 2012

Robots are already having a growing impact in many sectors

Logistics

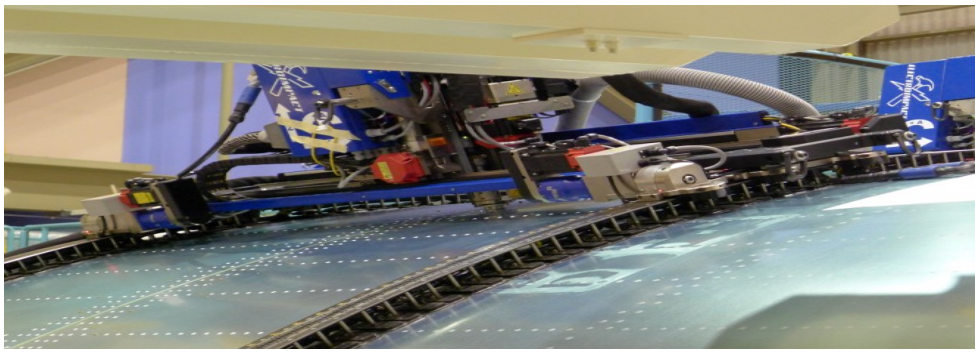
C&S Wholesale Grocers, America's largest food distributor, has eight robots working on each of the 21 floors of its largest distribution centre.[15] Their tasks include taking products off shelves and preparing them for delivery. Amazon also uses robots to perform similar functions in its warehouses, as can be seen in the photo below.

[11] "Coming home," *The Economist*, Jan. 19, 2013
[12] "Smarter Robots, With No Wage Demands," *Businessweek*, Sept. 18, 2012
[13] "Coming home," *The Economist*, Jan. 19, 2013
[14] "Smarter Robots, With No Wage Demands," *Businessweek*, Sept. 18, 2012
[15] "Skilled Work, Without the Worker," *The New York Times*, Aug. 18, 2012

Source: "Amazon's Kiva robots," Canadian Business, April 12, 2012

Manufacturing

Boeing is but one example of a manufacturer that has been steadily increasing its use of robots. It recently began employing robots to paint the wings of its 777 airplane. The robot can lay down a single coat of paint in 24 minutes, versus about four hours for a team of painters. Another robot is being used by Boeing to drill holes where sections of the fuselage are joined (see picture below). Since robots have taken over this task from humans, there has been a 98% improvement in hole quality.[16]



Source: "Newest addition to Boeing's workforce? Robots," Wired, June 14, 2013

Healthcare

The Food and Drug Administration recently approved the use of a robot called RP-VITA made by iRobot. It is a robot on wheels that permits doctors to communicate with patients from anywhere in the world (see picture below).[17] It can also access a patient's medical charts, x-rays and other information, and with the help of technicians conducts all sorts of tests directly on the patient.

[16] "Newest addition to Boeing's workforce? Robots," *Wired*, June 14, 2013
[17] "Autonomous Robots Coming To U.S. Hospitals," Fast Company, Jan. 24, 2013

The robot doctor at your service

Source: "Autonomous Robots Coming To U.S. Hospitals," Fast Company, Jan. 24, 2013

Another company called Remedi SeniorCare makes robots that package, label and dispatches medicines to patients. Having humans do it is both time-consuming and error-prone.[18] In 2008, 1.9 million people became ill or injured from medication side effects, or because they took or were given the wrong type or dose of medication, up from 1.2 million in 2004, according to the Agency for Healthcare Research and Quality.[19]

Mining

The British-Australian mining giant Rio Tinto announced plans last year to invest $518 million to develop the world's first long-haul, heavy-duty driverless train system at its Pilbara iron ore mines in Western Australia. The automated trains are projected to start running in 2014. Rio Tinto also plans to begin using driverless trucks and automated drills.[20]

Oil sector

Statoil, a Norwegian oil company, has projected that automation may cut in half the number of workers required on an offshore rig in the near future. Rig builder Drilling Structures International Inc. has recently began using remote control devices to get their drill rigs into place.[21]

Agriculture

Robots are also transforming the farming sector. One example is the milking machine produced by the Dutch company Lely called Astronaut A4, which significantly reduces the need for human labour. Once the cow has entered the cage (see below), a robotic arm moves under the cow, attaches suctions to the teat cups and begins milking in a matter of seconds. One of these machines can handle about 180 milkings a day. The cost for one of these machines is around $210,000.[22]

[18] "Jenkins: Robots to the Rescue?," *The Wall Street Journal*, Jan. 8, 2013
[19] "Medication-Related Injuries on the Rise," *The New York Times*, April 14, 2011
[20] "Practically human: Can smart machines do your jobs?," *Associated Press*, Jan. 25 , 2013
[21] "Robots: The Future of the Oil Industry," *Businessweek*, Aug. 30, 2012
[22] "The $210,00 cow-milking machine," *Businessweek*, Oct. 5, 2012

The Lely Astronaut A4 milking system

Source: Lelylife.com

3) The massive economic and geopolitical consequences of the robotics revolution

Historically, previous waves of innovation have eventually ended up creating more jobs than have been lost. For example, while the invention of the internal combustion engine put makers of horse-drawn carriages out of business, it did eventually lead to the creation of the auto industry. The same can be said for the mechanization of agricultural production starting in the twenties. Most farm workers eventually found better employment in urban areas. Today, about 2% of America's labour force works in farming, versus 40% in 1913.[23]

One major difference is that during past industrial revolutions lots of people were still needed to design, make and run the machines. When it comes to robotics, they are increasingly running themselves,[24] and will perhaps even be able to build themselves in the future.

Another difference is that earlier technological revolutions took place over many decades, thus giving societies more time to adjust. Erik Brynjolfsson, co-author of *Race Against the Machine*, said: "**The internal-combustion engine was developed in the latter half of the 19th century, but it displaced the horse as a means of transportation only some 50 years later. The World Wide Web, on the other hand, has upended industries in less than 20 years.**[25] The advance of robots is moving with similar speed.

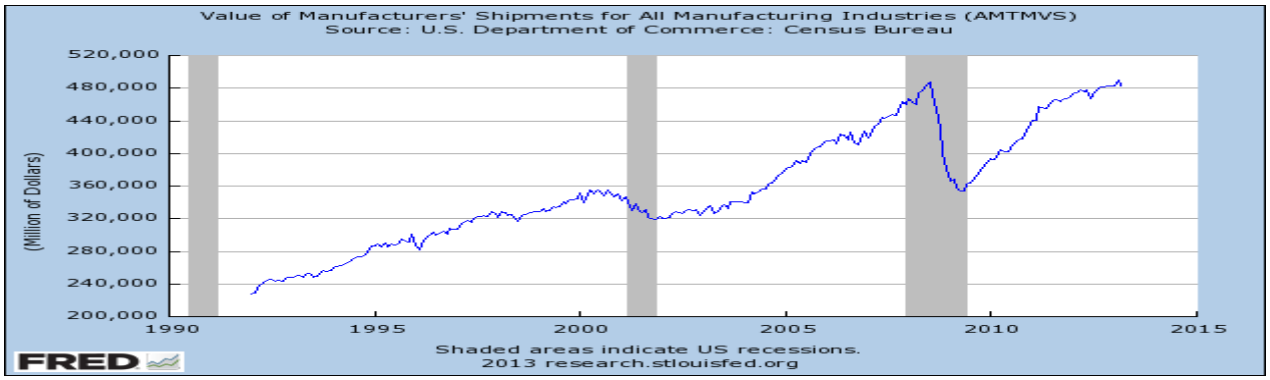
Also, even though previous transitions did lead to the creation of many new jobs, these changes were quite often associated with long periods of high unemployment during the adjustment process. For example, mechanization of the agricultural sector led to soaring food production in the twenties, and caused prices to plunge. This left farmers struggling to pay their debts,[26] and worsened the impact of the Great Depression.

[23] "Can Robots Bring Manufacturing Jobs Back to the U.S.?," *Time Magazine*, Sept. 27, 2012
[24] "Kevin Drum on why the robots will rise up and take all our jobs," *The Washington Post*, May 14, 2013
[25] "Robot Workers: Coexistence Is Possible," *Businessweek*, Dec. 13, 2012
[26] "Will smart machines create a world without work?," *Associate Press*, Jan. 25, 2013

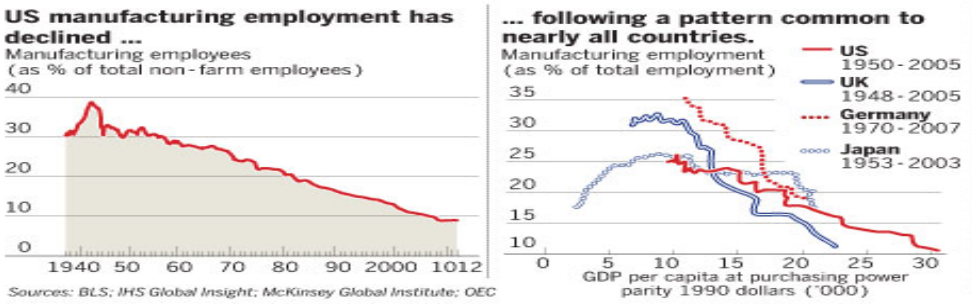
4) Increasing automation will lead to renewed questions over how wealth and work should be redistributed

Already today, as a result of increase in productivity and globalization, many countries are facing high unemployment levels even though their economies are growing. This is because a greater share of the income is going to capital rather than labour. **Indeed, while the total value of goods in the United States has steadily increased over many years (see chart below), the number of workers in the manufacturing sector has steadily declined.** The growing use of robots means that will only further intensify this trend.

The value of manufactured goods produced in the U.S.

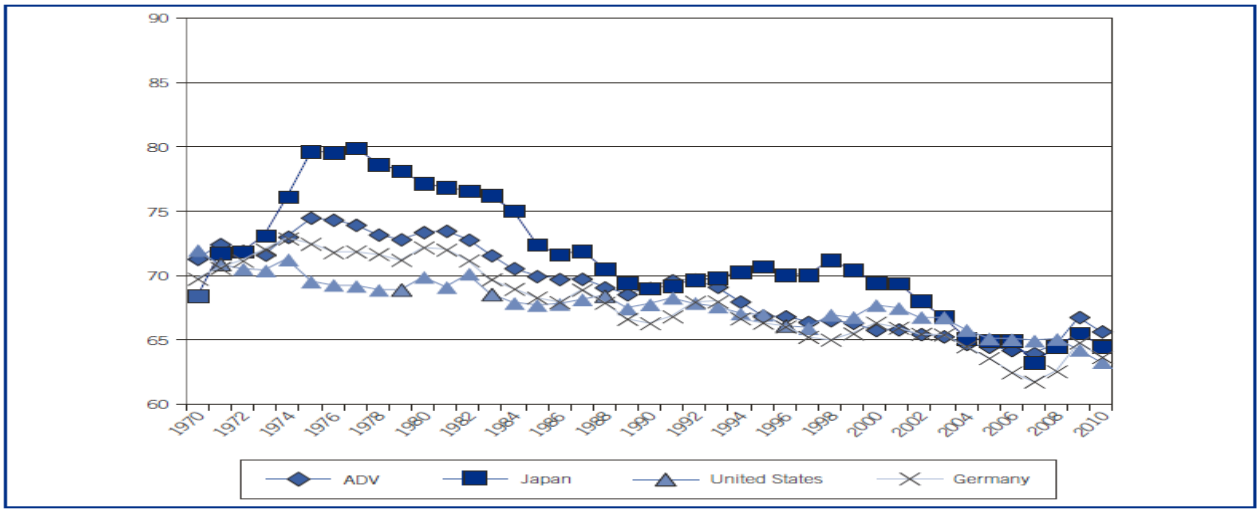


As the following charts indicate, declining industrial employment is a trend affecting most developed countries. This includes Germany, one the few developed world countries that has been lauded for maintaining a strong industrial sector.



Source: "American industry is on the move," The Financial Times, Jan. 8, 2013

Figure 31 Adjusted labour income shares in developed economies, Germany, the USA and Japan, 1970–2010

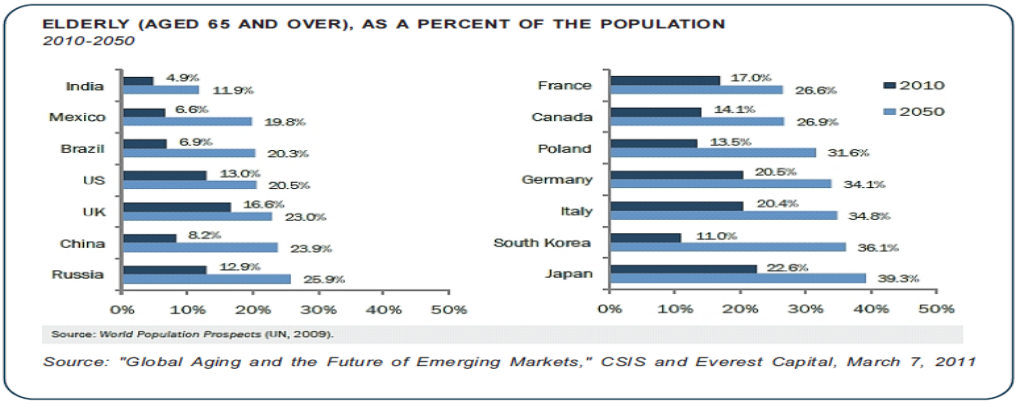


Note: ADV = unweighted average of 16 high-income OECD countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Spain, Sweden, the United Kingdom, and the United States. The Republic of Korea is excluded.)
Source: Stockhammer, forthcoming, from AMECO database.

Source: "Global Wage Report 2012/13," International Labour Organization, 2013

5) Robotics to the rescue of aging societies

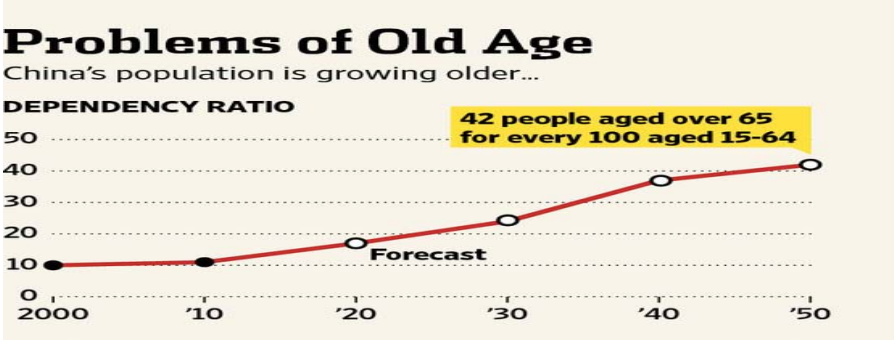
The biggest demographic-related challenge facing aging societies is the rising cost of healthcare, and the declining number of workers to finance the costs.



Robots offer the potential for huge healthcare savings. Similar to what has occurred in the manufacturing sector, robots will enhance productivity in the healthcare sector by, among other things, dramatically reducing errors and implementing labour-saving technologies. It will also help deal with growing healthcare labour shortages many countries are experiencing. In 2010, the Japanese government estimated nursing homes and hospitals needed two million caregivers to look after the country's 30 million elderly, but managed to attract only 1.3 million workers.[27] There is also a growing shortage of medical personnel in the United States. For example, the Association of American Medical Colleges projects there will be a shortage of 130,000 doctors in the United States by 2025.

[27] "Difference Engine: The caring robot," *The Economist*, May 14, 2013

Similarly, China's aging population is already causing labour markets to tighten and wages to increase substantially. These factors, plus recent labour unrest at its factories, have led Foxconn Technology Group, the company which builds the IPod for Apple, to significantly increase its use of robots. The company's goal is to have one million robots working in its Chinese factories within three years.[28] It currently has a human workforce of 1.4 million.



Source: "Aging Chinese Face a Bleak Picture," The Wall Street Journal, May 30, 2013

6) Overview and investment implications

Overall, we believe that the most likely outcome of the robotic revolution will be an unprecedented increase in productivity accompanied by a sharp reduction in demand for labour. Indeed, even the new professions eventually created by the robotic era will not be sufficient to replace all the jobs that have been lost. While all these developments have the potential to increase the quality of life globally, they also will bring to the forefront the debate over how work and wealth will be distributed on a societal level.

From an investment perspective, this represents a long-term bull market for maker of robots. Given the advanced technology that is required to produce higher-end robots, it is a sector currently dominated by developed-world companies. Below are examples of publicly-listed companies active in the robotics sector:

KUKA (Germany), **ABB** (Switzerland), **Rockwell Automation** (U.S.), **FANUC** and **Yaskawa** (both based in Japan) are among the largest manufacturers of industrial robots.

Cognex Corporation (U.S.) manufactures vision systems that analyze visual information in order to help automate manufacturing operations.

Adept Technology, Inc. (U.S.) is a company which specializes in building robots that package food.

Kiva Systems (recently purchased by Amazon) makes robots that retrieve and carry packages to their shipping points.

iRobot Corp. (U.S.) makes robots that clean pools and vacuum and mop floors. It also makes robots for the defence sector.

Intuitive Surgical and **Hansen Medical, Inc.** (both in the U.S) manufacture surgical robots.

[28] "The March of Robots Into Chinese Factories," *Businessweek*, Nov. 29, 2012

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