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Prof. Dr. Paul J.J. Welfens (EIIW)
President of the European Institute for International Economic Relations at the University of Wuppertal (EIIW); Jean Monnet Professor for European Economic Integration; chair for Macroeconomics
Rainer-Gruenter-Str. 21, D-42119 Wuppertal; +49 202 4391371; Alfred Grosser Professorship 2007/08, Sciences Po, Paris, Research Fellow, IZA, Bonn, Non-Resident Senior Fellow at AICGS/Johns Hopkins University, Washington D.C.
welfens@eiiw.uni-wuppertal.de, www.eiiw.eu;

Robotics, Jobs and Economic Systems: Dynamics and Challenges in the USA, Europe and China

Paper presented at CIFA International Forum, Monaco 2018,21-22 (15 min)

20 Years of EIIW: 2015 – Conference in Berlin and Wuppertal

- Award-winning research; *Euro Crisis anticipated in Oct 2008*
  National / International Networks

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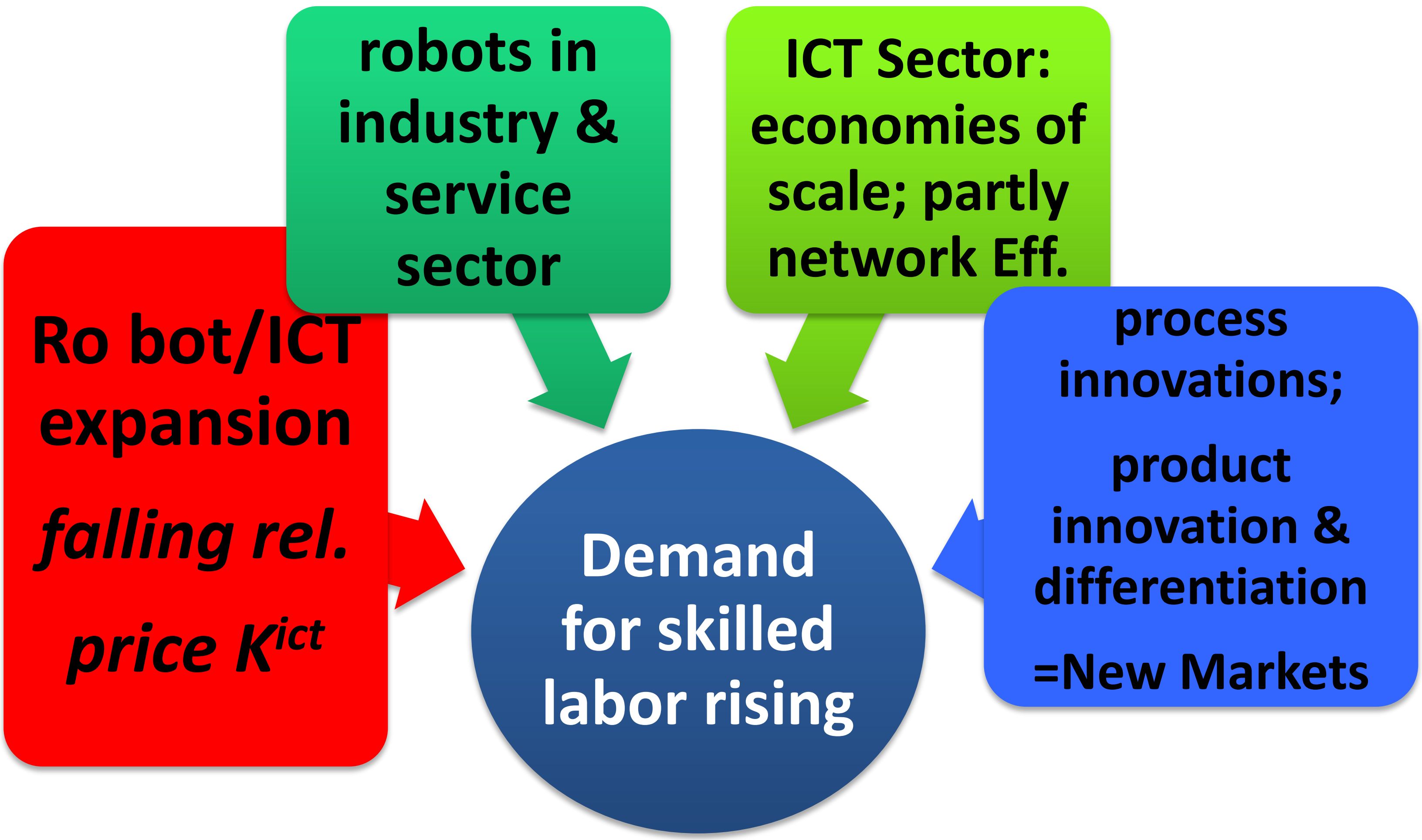
Outline

- 1) Introduction: Digital Economic Expansion
- 2) Robotics and ICT – Dynamics in the US, Europe and China
- 3) ICT-Driven Changes in Economic Systems
- 4) Job Losses in Germany, France, USA and China?
- 5) Speeding up, Skill Upgrading and Institutional Reforms in Leading OECD Countries
- 6) Whither Economic Systems in the EU, the US, China

Analytical Framework



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Key Issues

- **1) Expansion of robots which is not the same as expansion of Information & Communication Technology (ICT);**
  - **robots** raise productivity and wages, affect both unskilled and medium-skilled workers; **therefore no polarization effect**
  - **ICT as the broader digital technology seems to raise wage polarizatio (along with industrial imports from China:see OECD)**
- **2) Robots/ICT + economic globalization in a stable global system** = basis of global economic growth, rising per capita income in North and South = **wealth accumulation in N. & S.= higher global savings rate= higher demand for financial services**
- **3) If digital progress** would stall or if there is **deglobalization or global pol. Instability** **world output growth will slow-down = all kind of new conflicts that undermine prosperity**

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Germany: robots use by sector; asymmetric

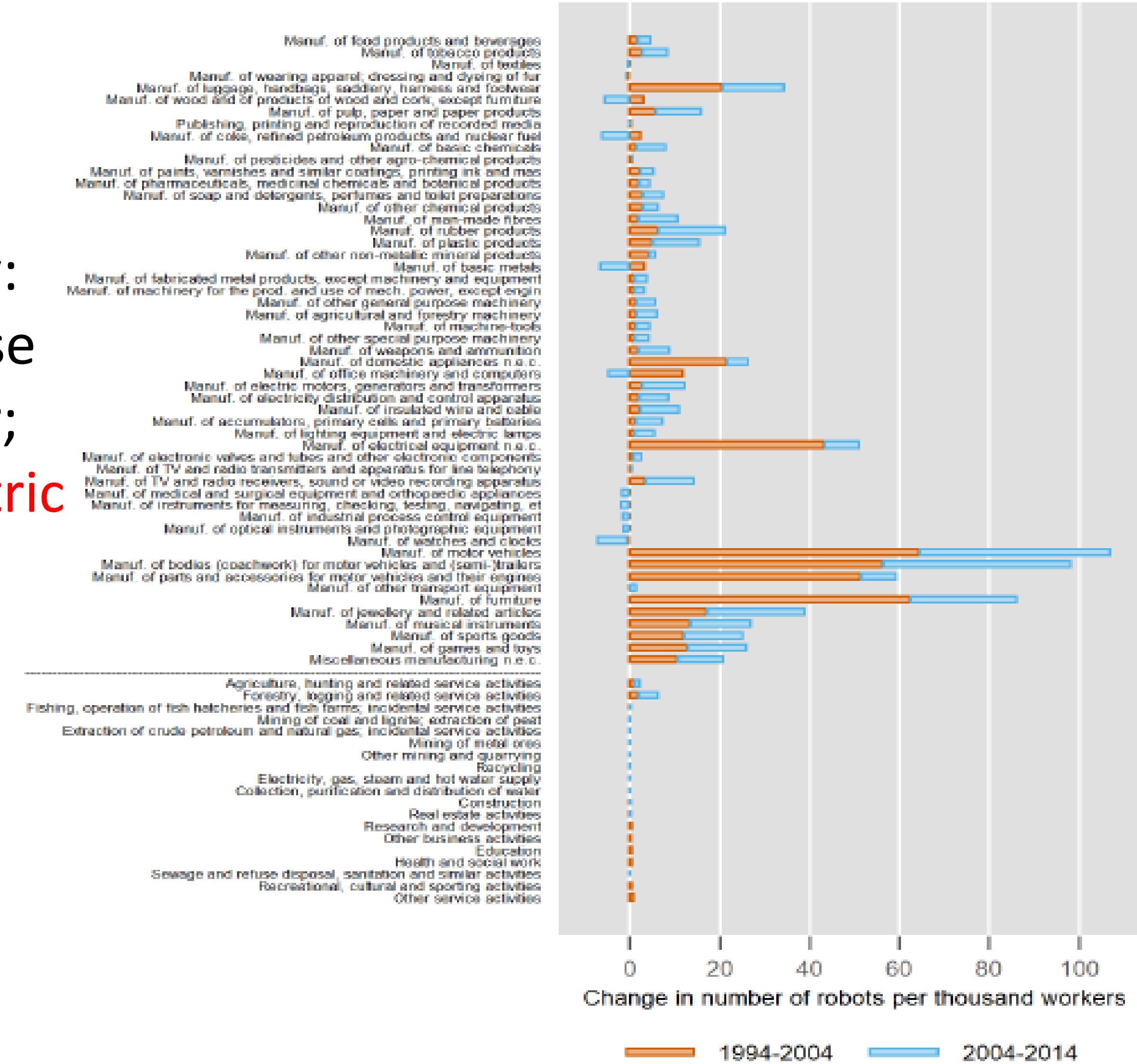

Figure 2: Industry-level distribution of robots

Notes: The figure displays the change in the number of robots per thousand workers by WZ 1993 industries (German Classification of Economic Activities, Edition 1993), for the two subperiods 1994-2004 and 2004-2014. Data for non-manufacturing industries in the first decade are only from 1998-2004.
Source: International Federation of Robotics (IFR)

Source:
The Research Institute of the Federal Employment Agency, Discussion Paper, 30/2017

Economic Digital Challenge

- 1) **Use of robots expanding** – difference across sectors; rise of **high-skilled employment**
- 2) **Industry4.0:** Who gains – Siemens/SAP/Dassault Systems or the leading 5 US digital social media companies & 2-3 companies from Asia?
- **3) Europa rather weak in digital platform services**
  - **e.g. Uber = digital mobility services concept**
  - **Next: Flyber? = digital air travelling concept?** Established flight companies fighting to control the markets: Machineber = enormous economic

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Perspective: Technology-Prices-Demand-Growth: ATM Example from the US

- **1) Rationalization effects = less jobs**
- **2) Services prices fall** = **more bank branches are profitable = banks need to hire new workers; also banks have developed new „advanced" banking services** = more complex and useful products = higher profits = basis for sectoral growth
- 3) how many (intra-/extra-sectoral) **innovation spillovers**?

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NEW Digital Economic Expansion (compared to previous structural change)

- **Very fast** global expansion= unusual challenge for many
- **Cross Innovation:** e.g. ICT & Automotive, ICT and Health Care – **makes it rather complex challenge** and emphasizes innovation dynamics
- **Software beats digital equipment:** Whenever possible flexible software replaces hardware
  - Software sector with specific challenges: 1) global, 2) as start-up you have no collateral = need for more collateral, 3) big companies are rather rare; and if big they are GLOBAL (e.g. SAP in Germany, Dassault Systems in France, Philips NL)
  - **IAB analysis in Germany** shows that skilled digital workers **with more tasks= job enrichment** = contrary to traditional hyperspecialization pressure;

  - **Platform Economics & dig. social networks/value of data**

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The Value of Data

- **How much higher the Gross Domestic Product (GDP) was due to trade in data: Trade volume of goods and services which are based on data and information in 2016 (million Euro)**

	Value of Data-based Trade (2016)	Share of GDP (in %)
USA	129,174	0.78
Japan	25,513	0.93
United Kingdom	13,313	2.56
Germany	12,925	2.45
France	7,427	1.70
Brazil	6,049	0.16
Italy	4,606	1.69
Netherlands	3,395	2.38
Spain	3,261	1.87
Sweden	2,304	1.85
Poland	1,691	1.09
Belgium	1,540	1.83
Denmark	1,283	2.37
Austria	1,257	2.15
Ireland	1,042	1.91

Note: Care should be exercised in interpreting the data for Brazil, Japan and the US as the comparability of the GDP effects is weakened due to a lack of the effect of the customers of data firms (e.g. revenues) and the related induced effects (e.g. higher tax revenues, higher wages)

Source: Adapted from Institut der deutschen Wirtschaft (2018), iwd, #9, table “Der Wert der Daten“, p. 10.; based on International Data Corporation (study for the European Commission)

Analytical Basis

- **Job losses** in OECD countries
  - Partly due to **expansion of information & communication tchnologies**
  - **Partly due to rise of industrial imports from China** – leads to loss of jobs with medium wages**= *leads to wage polarization***
    - *Particular risk for „middle jobs"; what to do with losers in structural change shaped by digitization and globalization (here China's expansion)*
    - ***California as a good example** of digital success (also ahead in the US= interesting!!): **so many new jobs, no unemployment, but a problem with affordable rents** for low skilled workers and certain immigrants*

Digital Global Perspectives

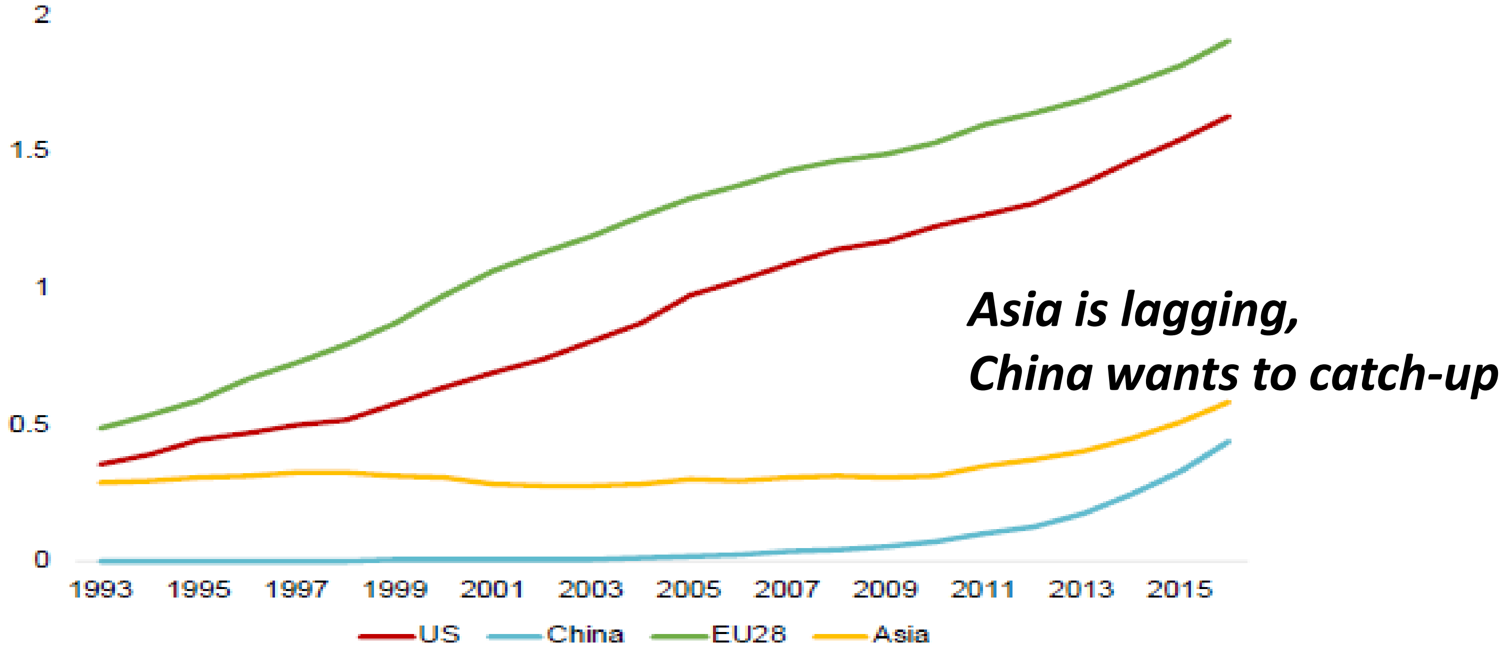
- **1)Maniyaka (2017, McKinsey 2017): Technology, jobs, and the future of work**
  - **½ of global population not online**
  - **Eliminating the digital gap in the South – and parts of the North= more jobs, higher GDP, particularly for women and the elderly;**
  - **only 5% of jobs could be fully automated in the short run, much depends on wages & price dynamics**

- **2) Digital economy is global – unclear framework**
  - **Will be difficult to tax digital income adequately= weaker states...**
  - **Will be difficult to have consistent effective global digital regulation (e.g. G20; ITU); China AND Russia do not want global regulation; US wants not much interference from EU and others; US support for WTO and digital *trade rules (products vs. services) is declining under Trump; US & China firms dominate***
  - **World Summit on the Information Society project should be continued! G20 & ITU could start new joint initiative**

A Look at International and EU Statistics

Robot Density in the US, China, EU28, Asia

Figure 1: Robot density
(robots per 1000 workers)

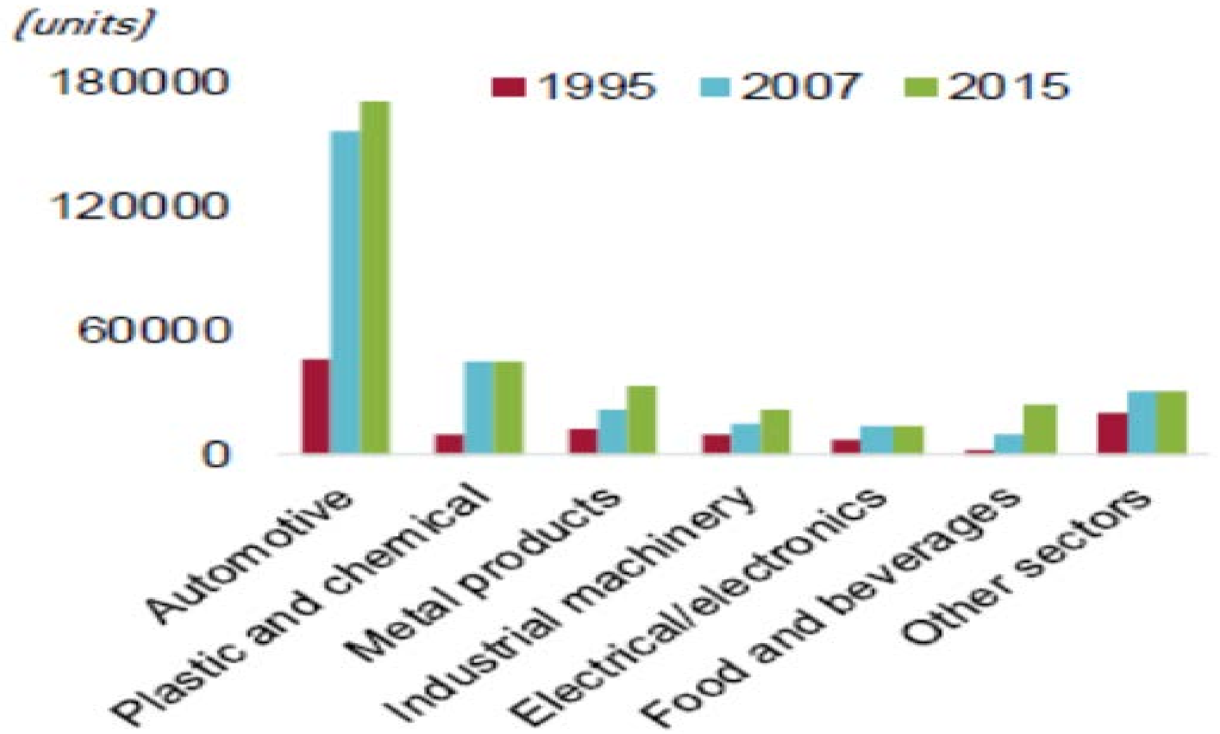


Source: Calculations based on IFR and EU-KLEMS

Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 5.

Sectoral Industr. Robotization View in the EU: Automotive Is Clear Leader

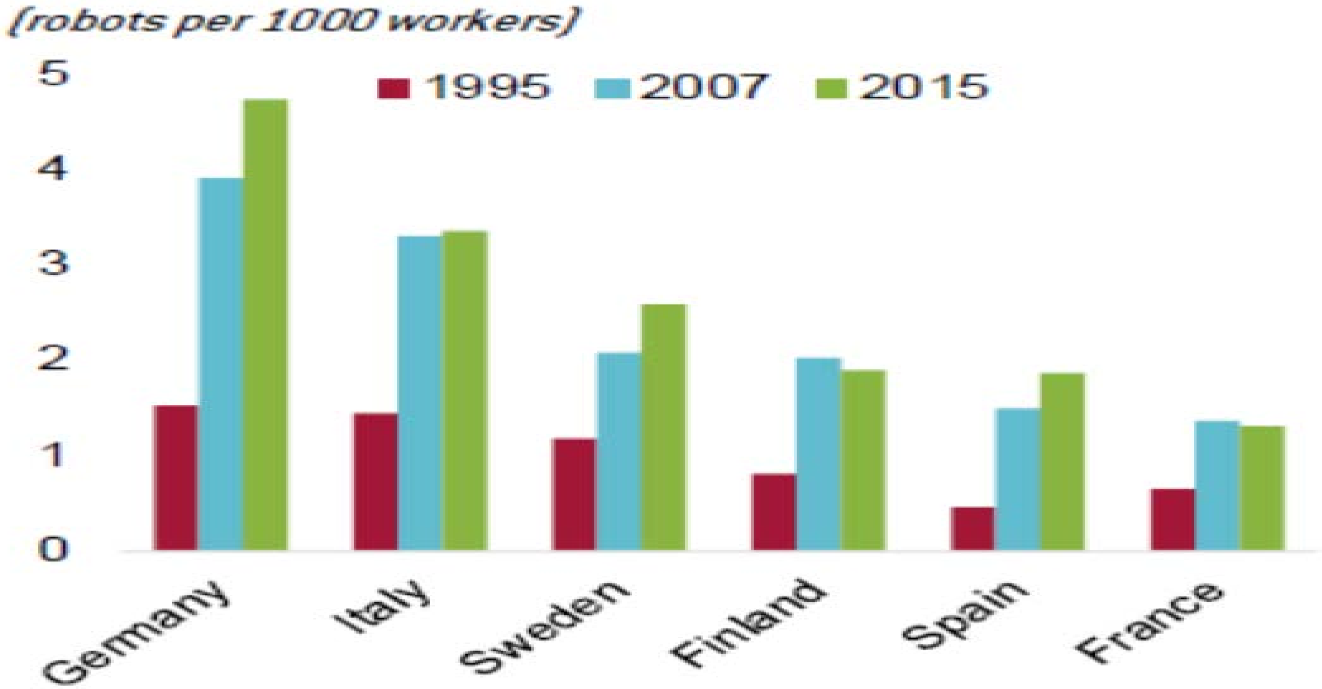
Figure 2: Number of industrial robots, by sector



Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 5.

Robot Density Per 1000 Workers Selected EU Countries

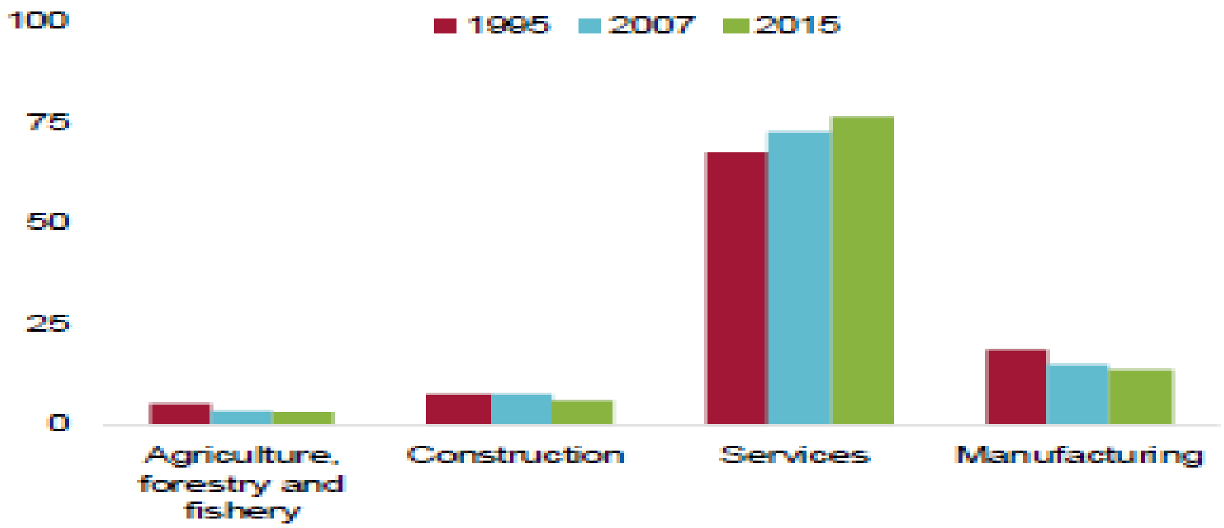
Figure 3: Robot density by country



Note: Displayed sectors are a subcategory of manufacturing while "Other sectors" also includes non-manufacturing sectors. Data for Sweden, Finland, Denmark, Germany, Spain, France, Italy, UK. Calculations for robots per 1000 are based on employment in the total economy in the respective year.
Source: IFR , EU-KLEMS.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 6.

Sectoral Employment Shares in Selected Group of Euro-12 Countries

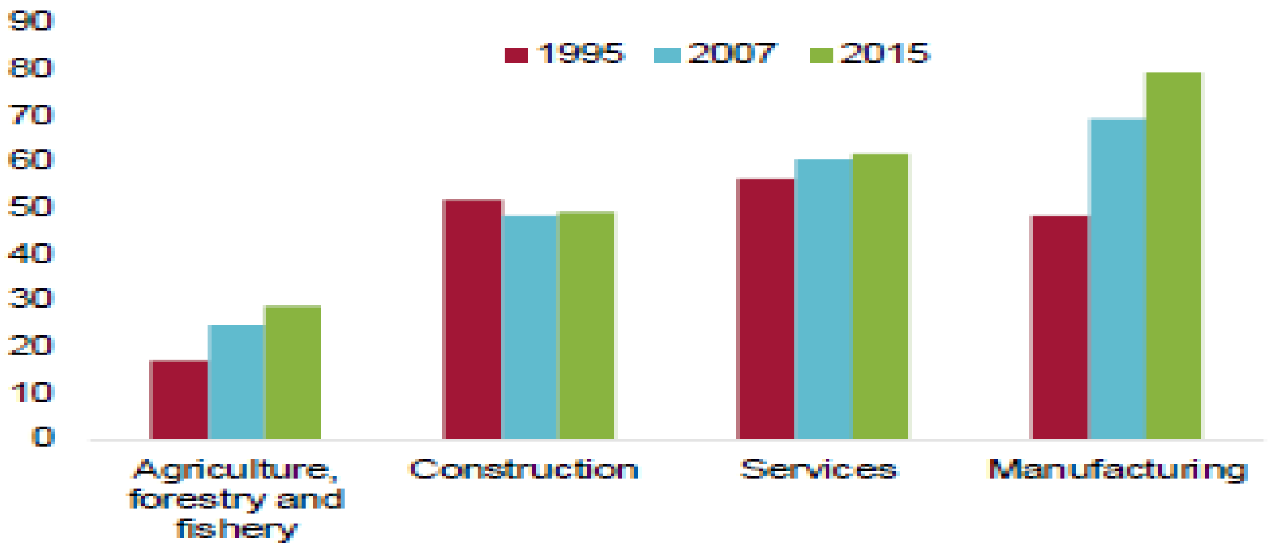
Figure 6: Employment shares by sector
(percentage shares)



Note: Based on Euro Area-12 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.
Source: AMECO.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 7.

Labour Productivity in Euro Area12 by Sector

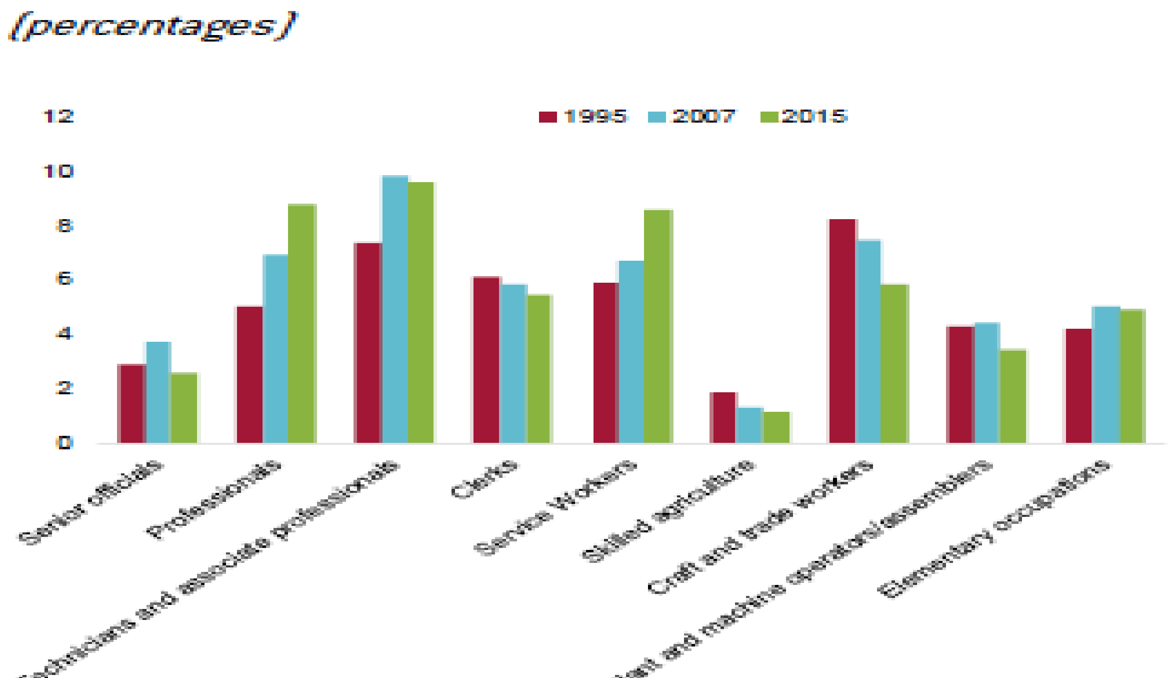
Figure 7: Gross value added per employed person by sector
(1000 euros per worker)



Note: Based on Euro Area-12 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.
Source: AMECO.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 7.

Employment Rate – by Occupational Group in the Total Economy (Selected EU Countries)

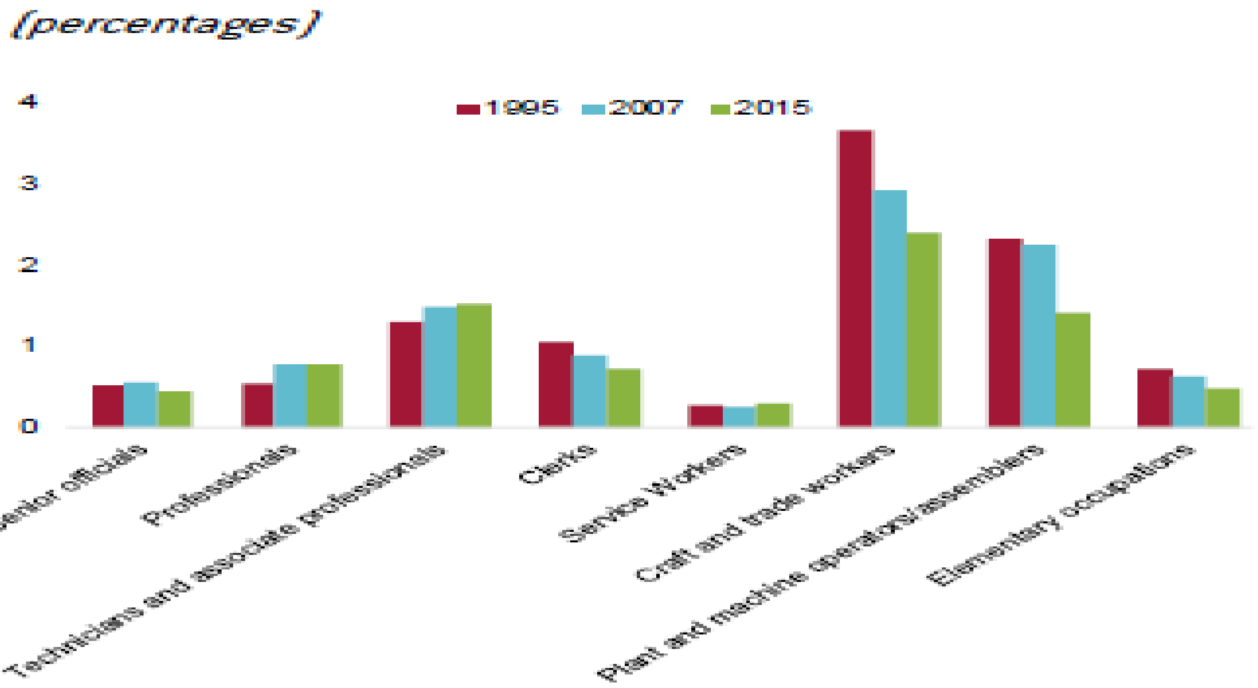
Figure 8a: Employment rate, by occupational group in the total economy



Note: Based on same six EU countries as in our analysis; employment rate based on population older than 15 years.
Source: Own calculations based on Eurostat LFS microdata.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 8.

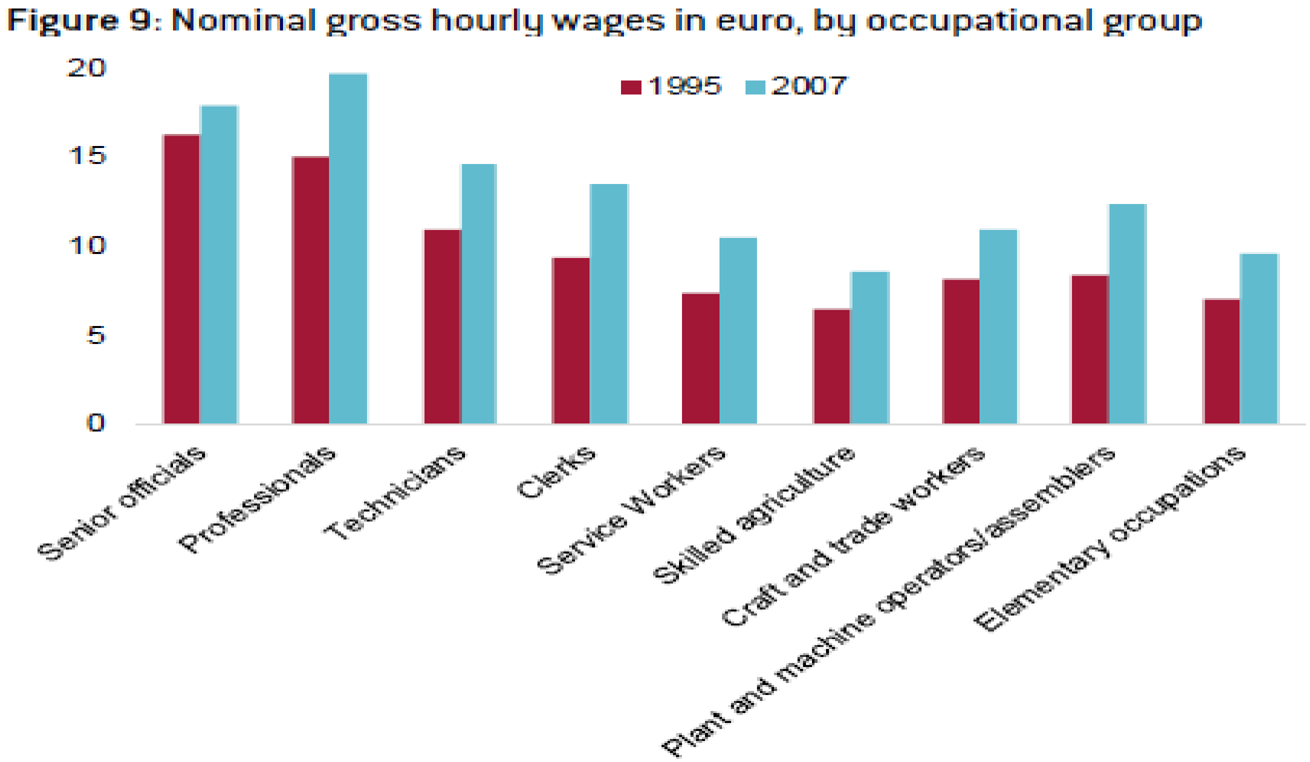
Employment Rate by Occupational Group (Selected EU Countries)

Figure 8b: Employment rate, by occupational group in the manufacturing sector



Note: Based on same six EU countries as in our analysis; employment rate based on population older than 15 years
Source: Own calculations based on Eurostat LFS microdata.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 8.

Hourly Wages by Occupational Group in Selected EU Countries



Note: Based on same six EU countries as in our analysis; sample includes population older than 15 years.
Source: Own calculations based on Eurostat LFS microdata.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 8.

Findings of Südekum et al.(2017) on Germany: Robots will bring gross job losses but no net job loss – problem is decline of wage income-GDP ratio= +inequality; .robots raise labor productivity but not wages.

- „We find **no evidence that robots cause total job losses, but they do affect the composition of aggregate employment. Every robot destroys two manufacturing jobs.**
- This indeed accounts for almost **23% of the overall decline of manufacturing** employment in Germany over the period 1994–2014, roughly 275,000 jobs. But this loss was fully offset by additional jobs in the service sector. Moreover, robots have not raised the displacement risk for incumbent manufacturing workers. **Quite in contrast, more robot exposed workers are even more likely to remain employed** in their original workplace, though not necessarily performing the same tasks, and the aggregate manufacturing decline is solely driven by fewer new jobs for young labor market entrants**.**
- **This enhanced job stability for insiders comes at the cost of lower wages. The negative impact of robots on individual earnings arises mainly for medium-skilled workers in machine-operating occupations, while high-skilled managers gain.** ..

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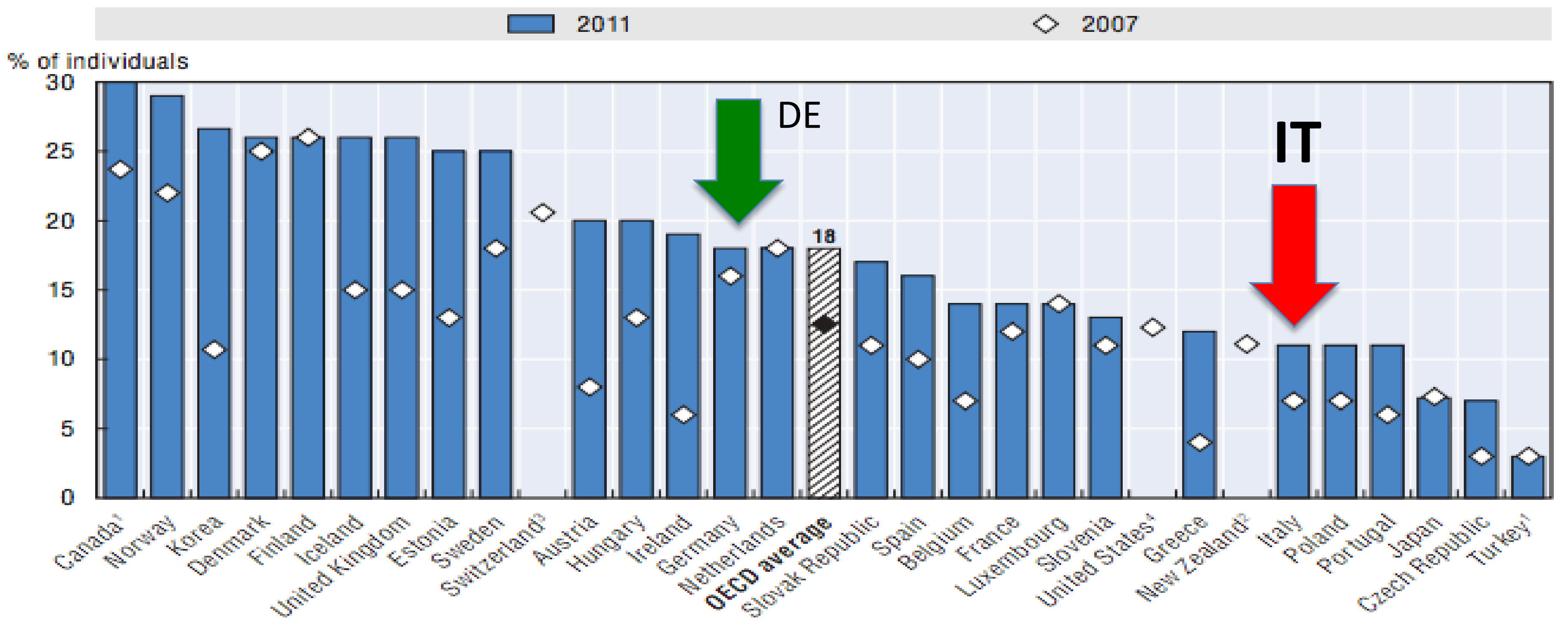
Multiple Job Challenge: ICT/Robotics and Employent

- **1) make country a leader in digital technology:** leaders always win the productivity race – see California/US, Korea, Japan, Taiwan, China
- **2) computer science in high schools not sufficiently established**; same in universities/applied universities (consider example of Berkely!)
- **3) how to avoid digital divide:** integrate everyboy in society (apply to North-South)
- **4) where could government assume a leadership role: E-government, E-health** (bad example of Germany; better is Austria, also Switzerland); digital education AND retraining; and where are the best performers in EU = basis for benchmarking – visit Estonia (ok, small and young= easier)
- **5) Job search: Make sure that country is leader in digital job-matching**= lower unemployment rate (leader in OECD is Canada; surprisingly poor performance Italy, Spain, Portugal; Germany is not a leader so far)

Figure 3.19: Individuals in that used internet for job search(2011 or latest available year): ACTIVE benchmarking needed – why not use EU money to reward the top RELATIVE improvements (Top 3 Relative Olympics!)



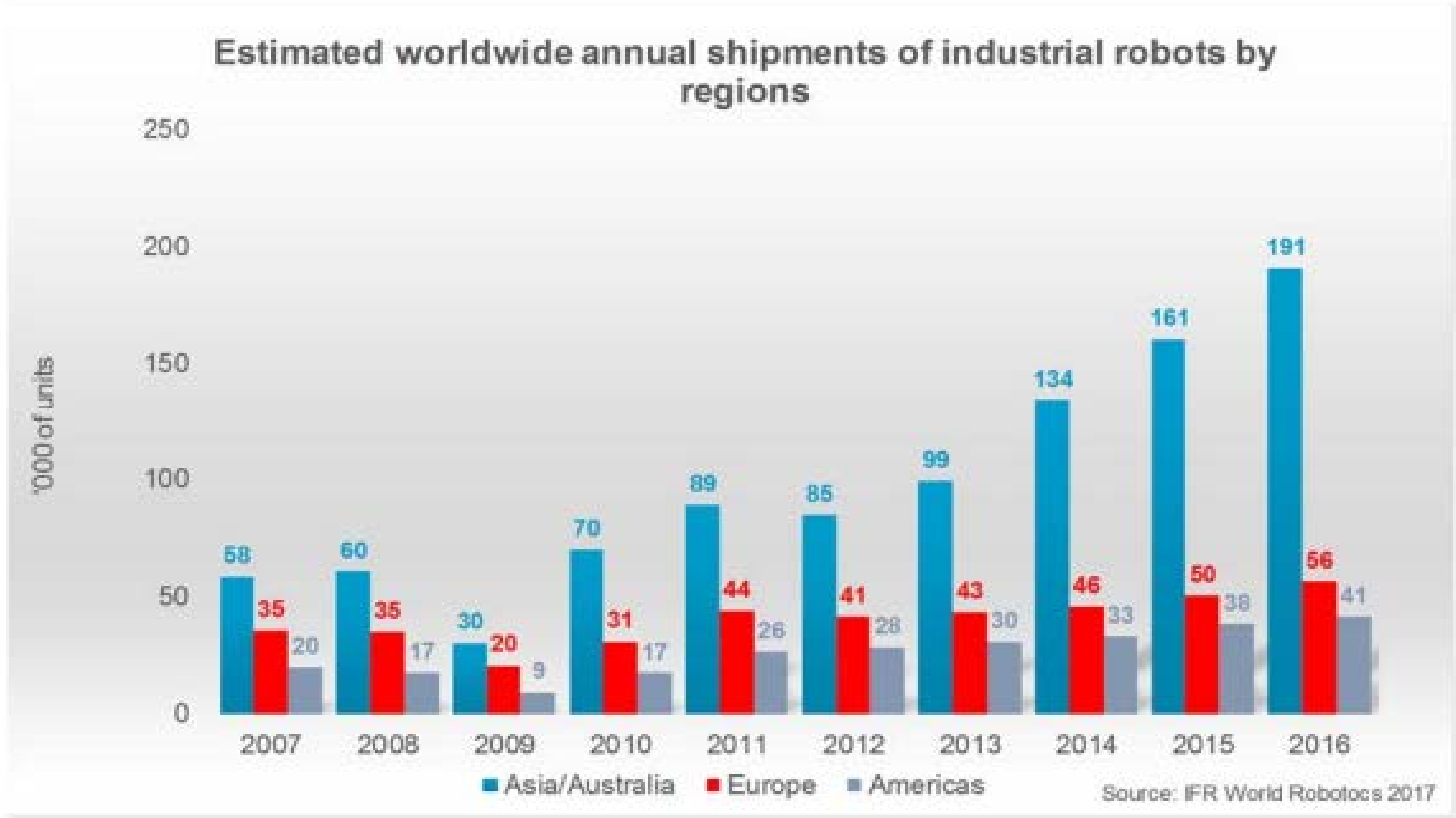
Note: Data from the EU Community Survey covers EU countries plus Iceland, Norway and Turkey. Individuals aged 16-74 years, except for Canada (16+), Japan (6+), Switzerland (14+). For countries covered by Eurostat, individuals were asked about activities they had carried out on the Internet in the last three months. For the other OECD countries, it generally refers to the last 12 months. Data refer for Eurostat countries to individuals who used the Internet in the last three months for job research or for sending job applications. Country notes: For Switzerland: Data refer to Internet users who used the Internet at least once within the last six months.

1) 2010; 2) 2006; 3) 2005; 4) 2003.

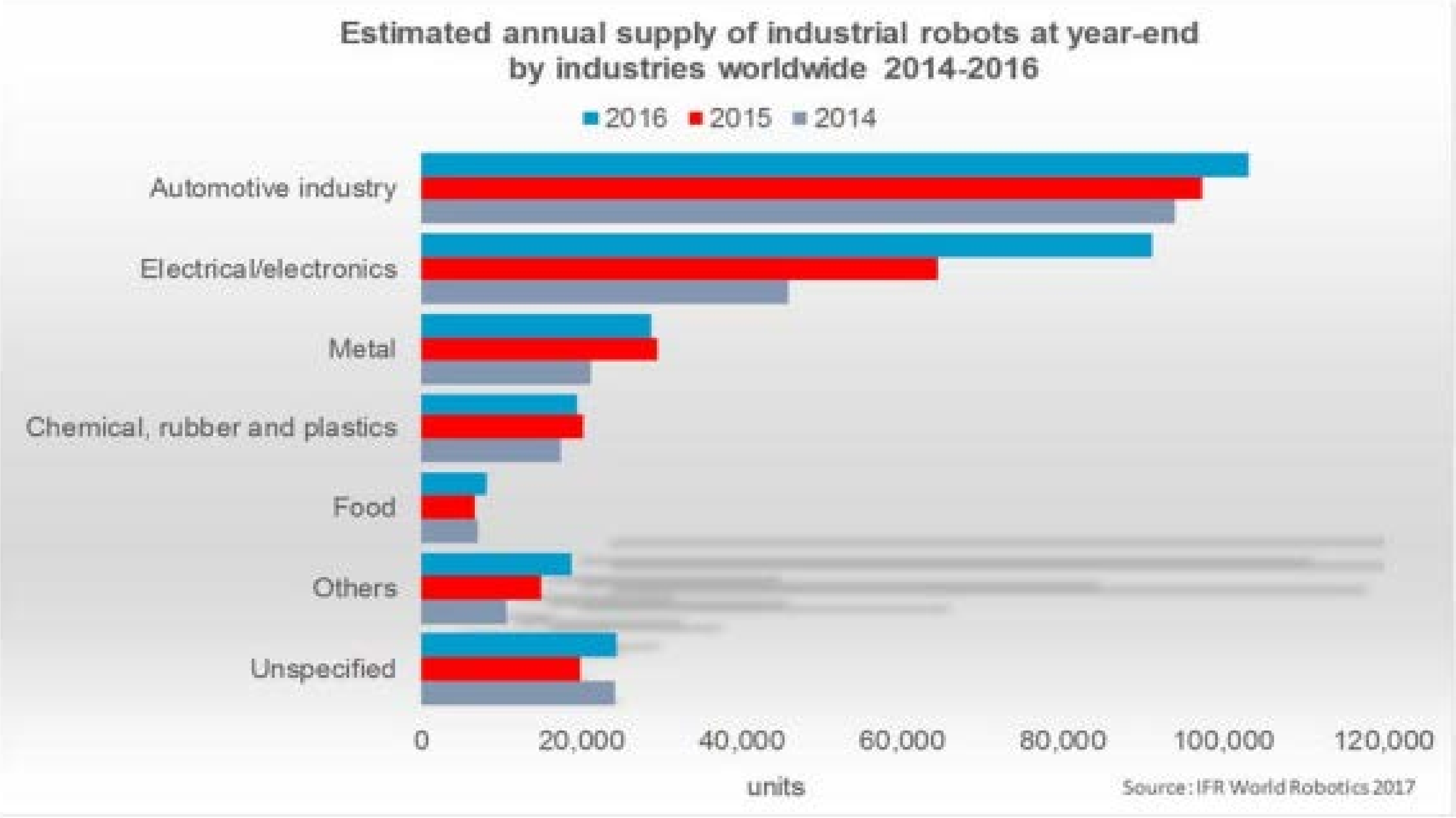
Source: *OECD ICT Database* and Eurostat Community Survey on ICT usage in households and by individuals, May 2012. Canadian Internet Use Survey, 2010 from Statistics Canada.

Industrial Robots

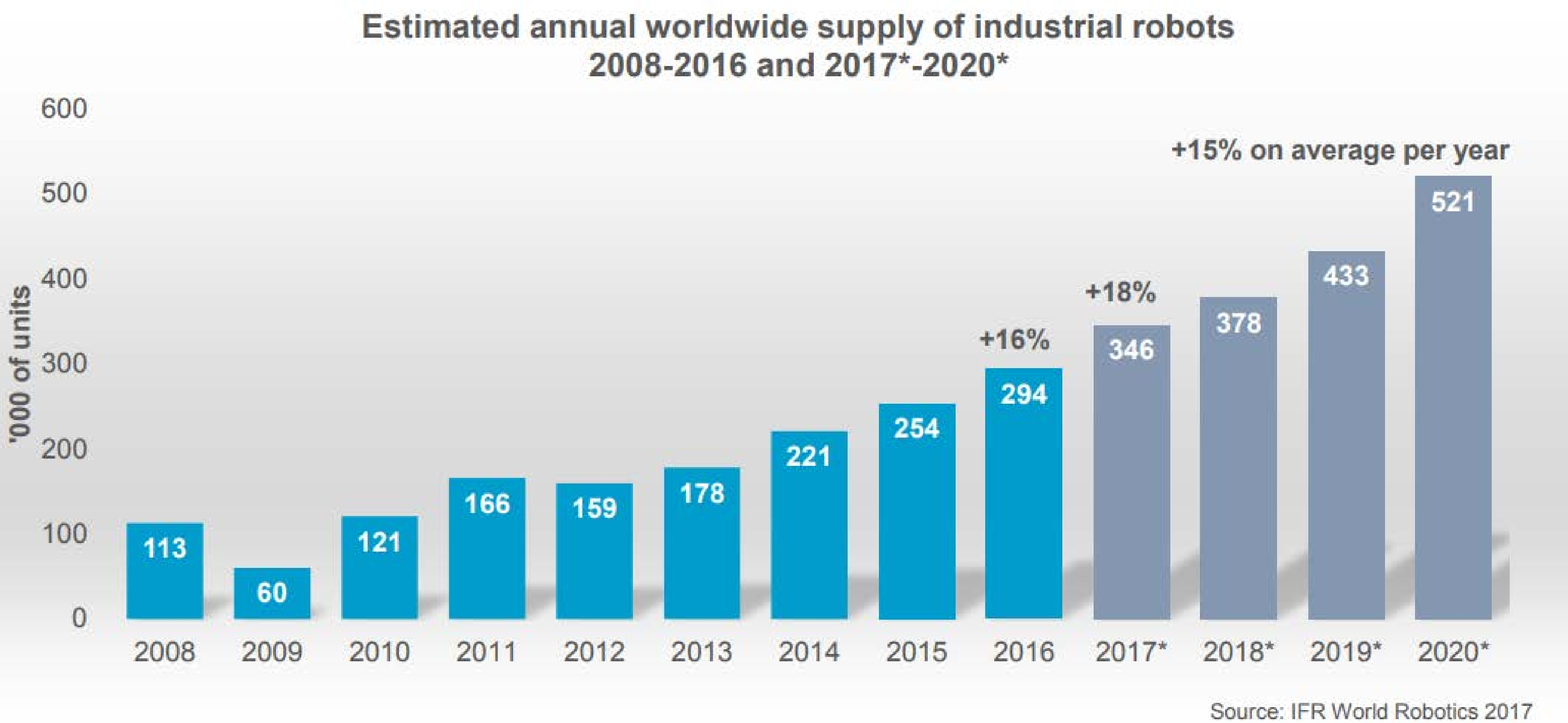
US+Canada (& Mexico) is a clear global leader



Robots' expansion differs across sectors



Robots expansion is impressive, but software business is even better..



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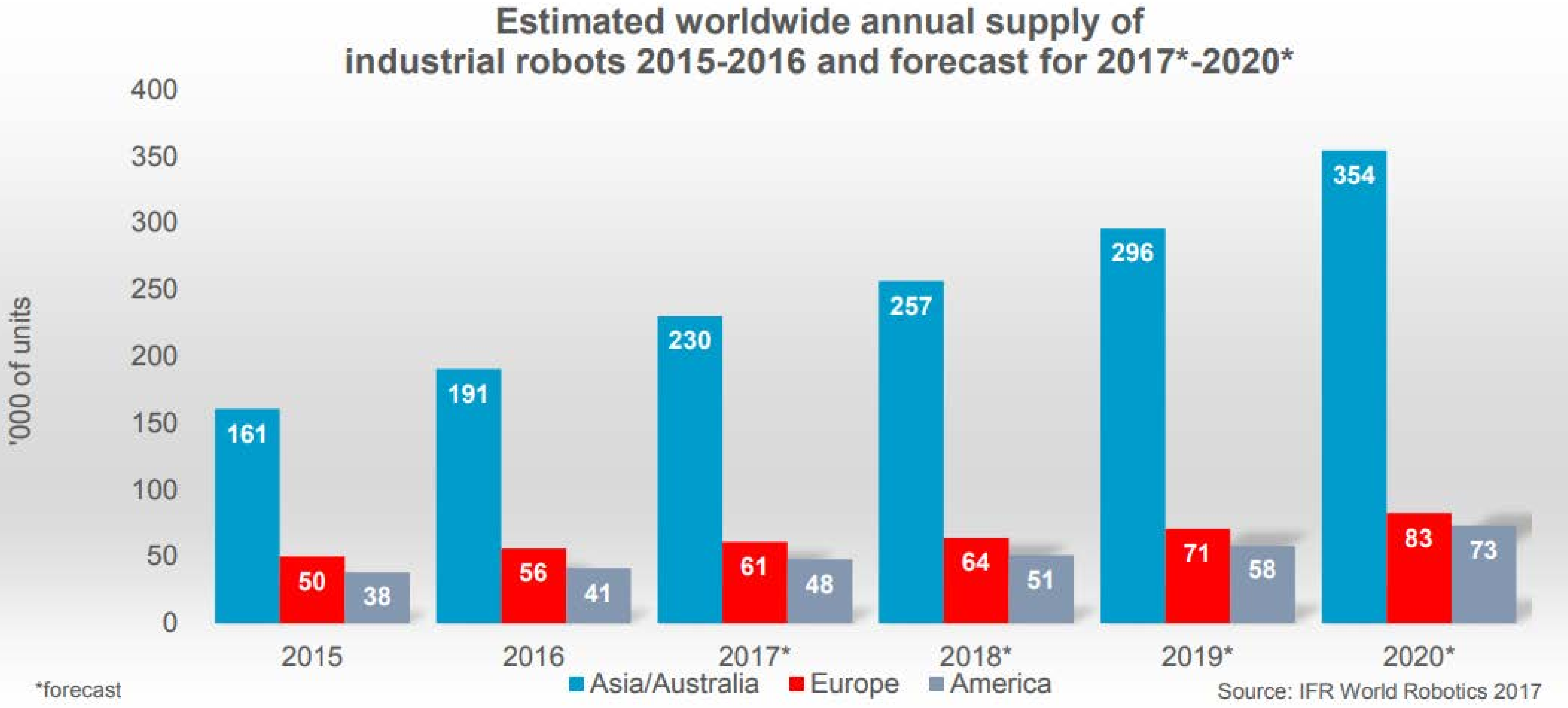
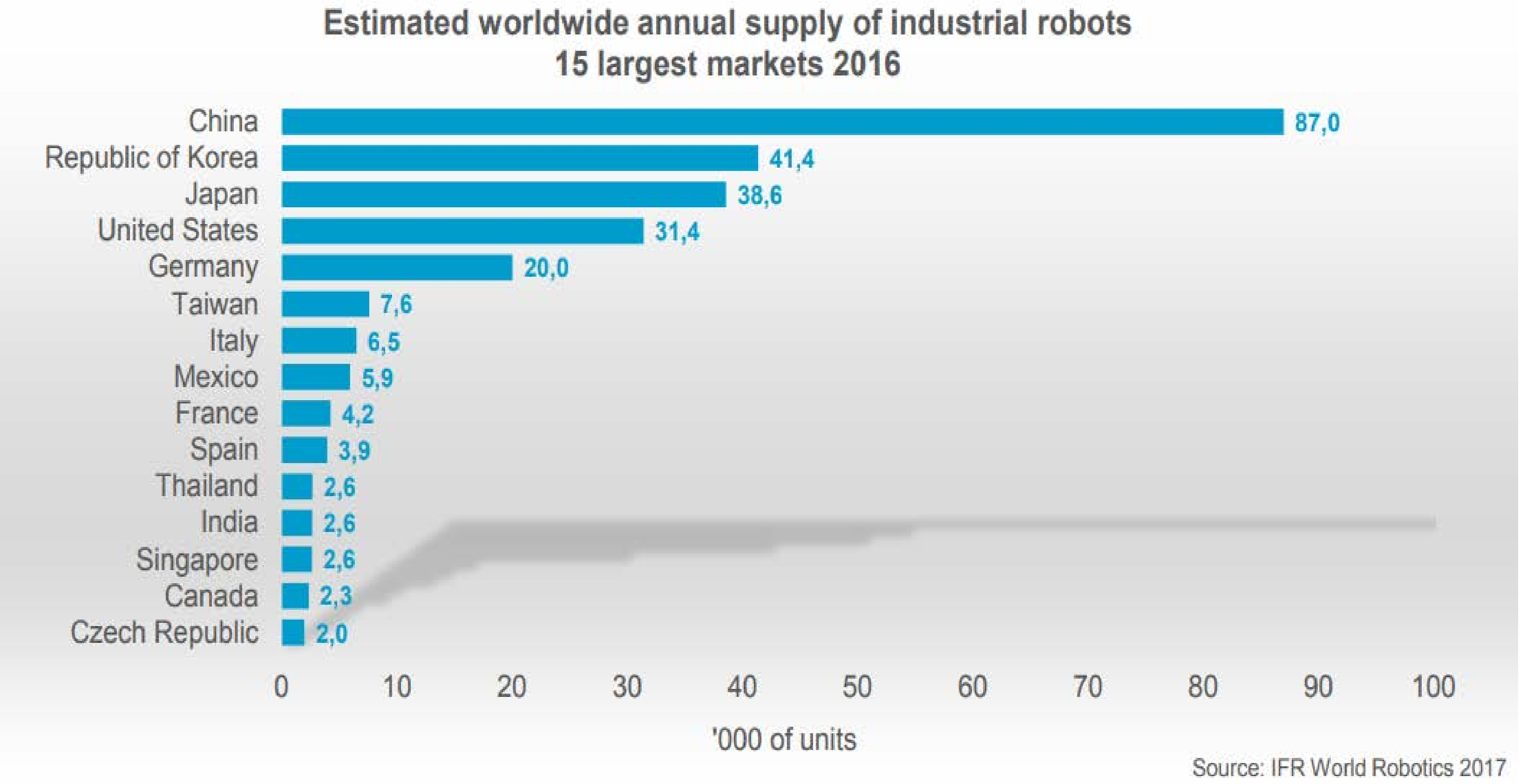

Estimated worldwide annual supply of
industrial robots 2015-2016 and forecast for 2017*-2020*
'000 of units
400
350
300
250
200
150
100
50
0
161
50
38
191
56
41
230
61
48
257
64
51
296
71
58
354
83
73
2015
2016
2017*
2018*
2019*
2020*
*forecast
Asia/Australia
Europe
America
Source: IFR World Robotics 2017

China, Korea, Japan, US, Germany, Taiwan, Italy, Mexico, France



Service Robots

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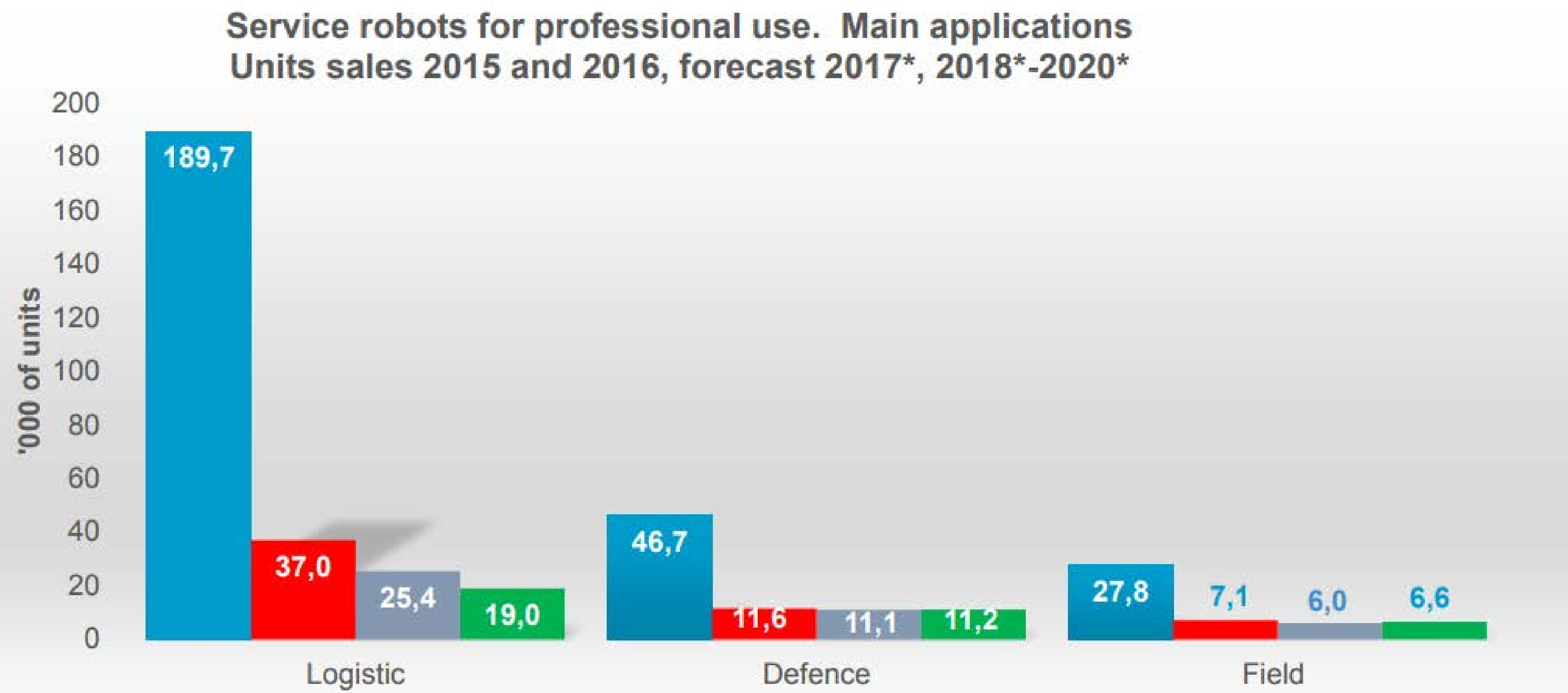
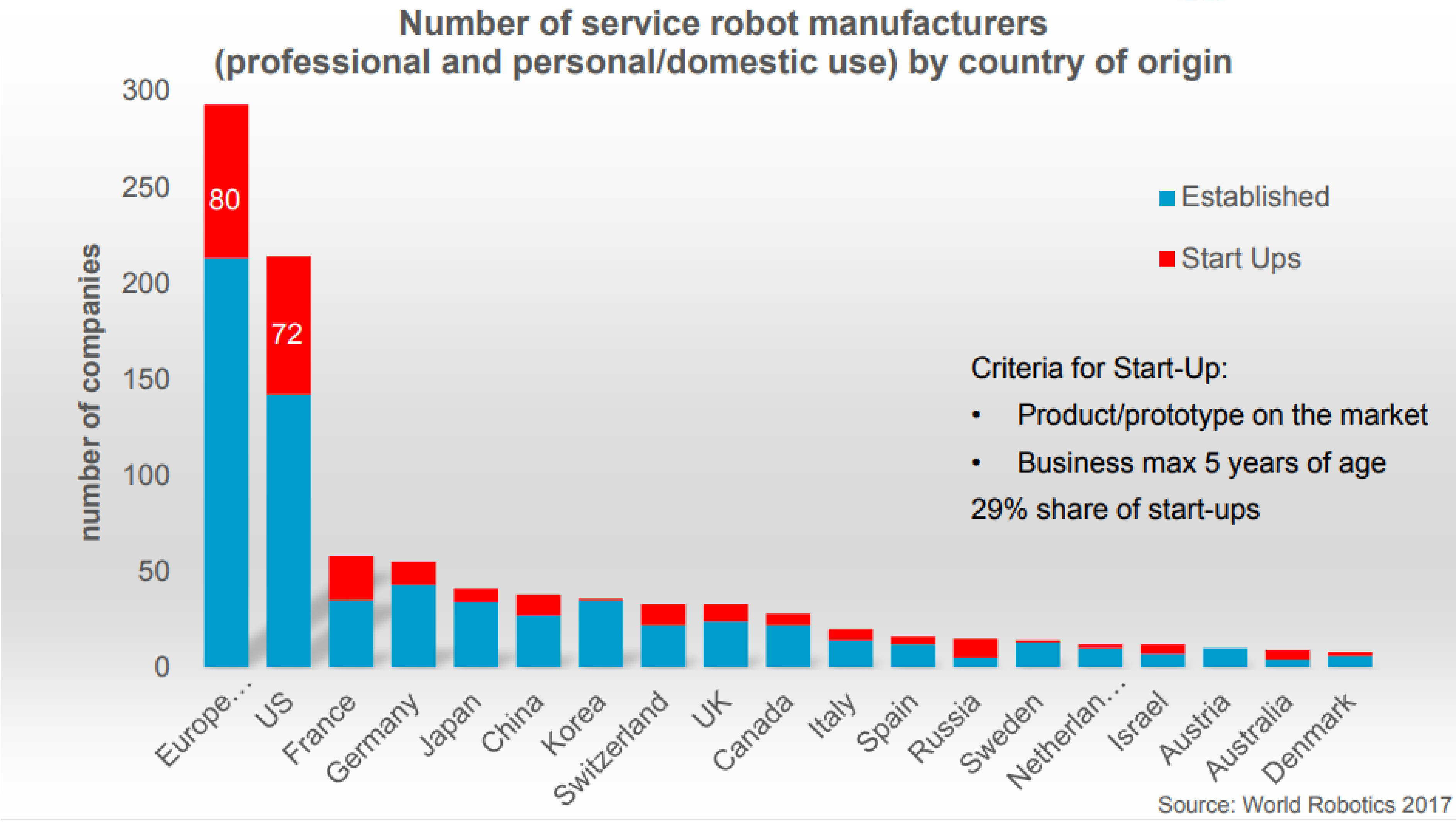
Service Robots will expand rather fast after 2020 when ageing and lack of skilled workers generate rising demand for such robots



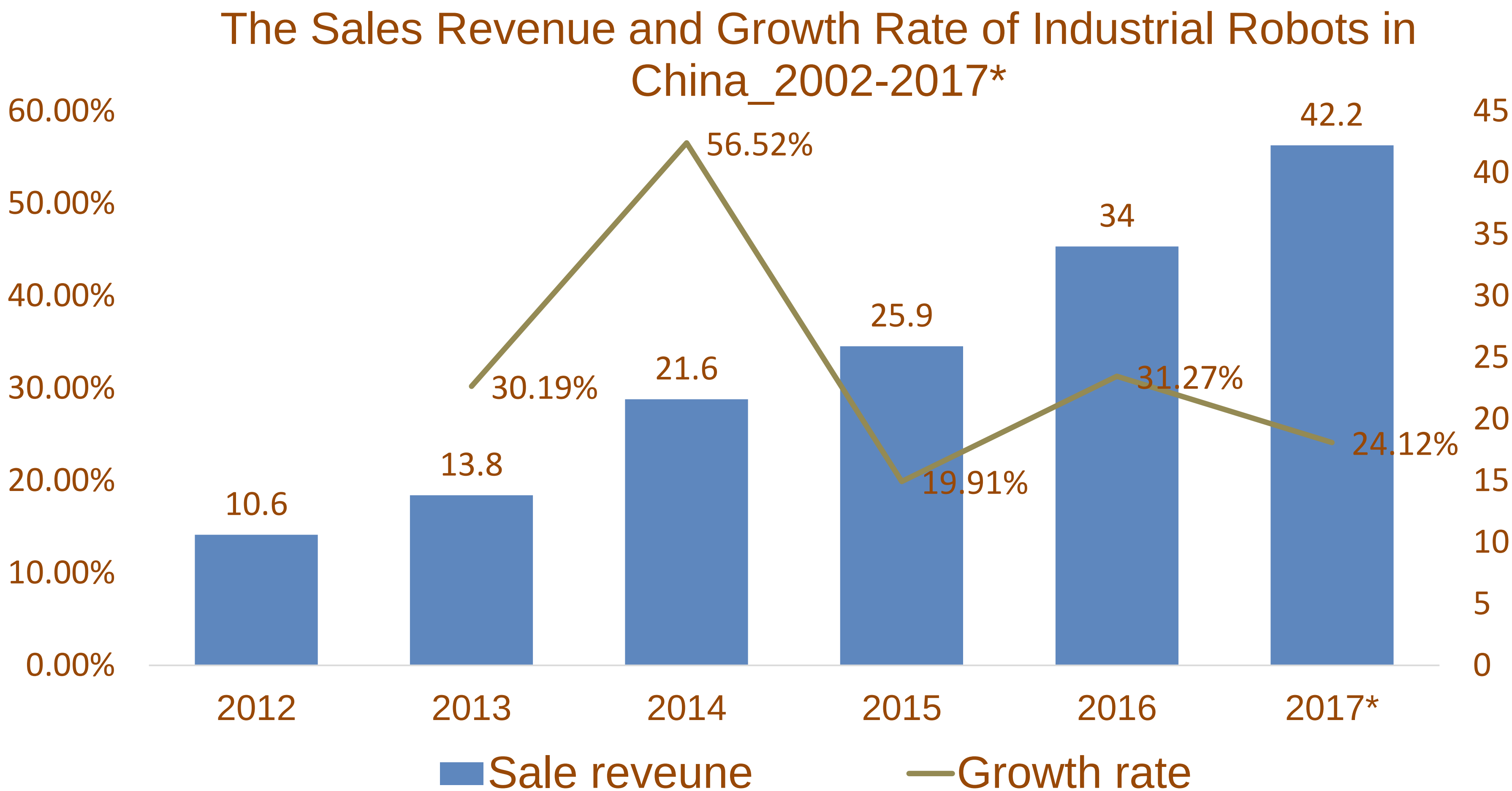
*forecast

Source: World Robotics 2017


Number of service robot manufacturers
(professional and personal/domestic use) by country of origin
300
250
200
150
100
50
0
number of companies
80
72
Established
Start Ups
Criteria for Start-Up:
• Product/prototype on the market
• Business max 5 years of age
29% share of start-ups
Europe…
US
France
Germany
Japan
China
Korea
Switzerland
UK
Canada
Italy
Spain
Russia
Sweden
Netherlan…
Israel
Austria
Australia
Denmark
Source: World Robotics 2017

Robotics in China: Government strongly interested in Industry 4.0;
and in promoting digital networking;
achieving global co-leadership in Artificial Intelligence; advantage: big home market, *overseas Chinese in the US & Europe*

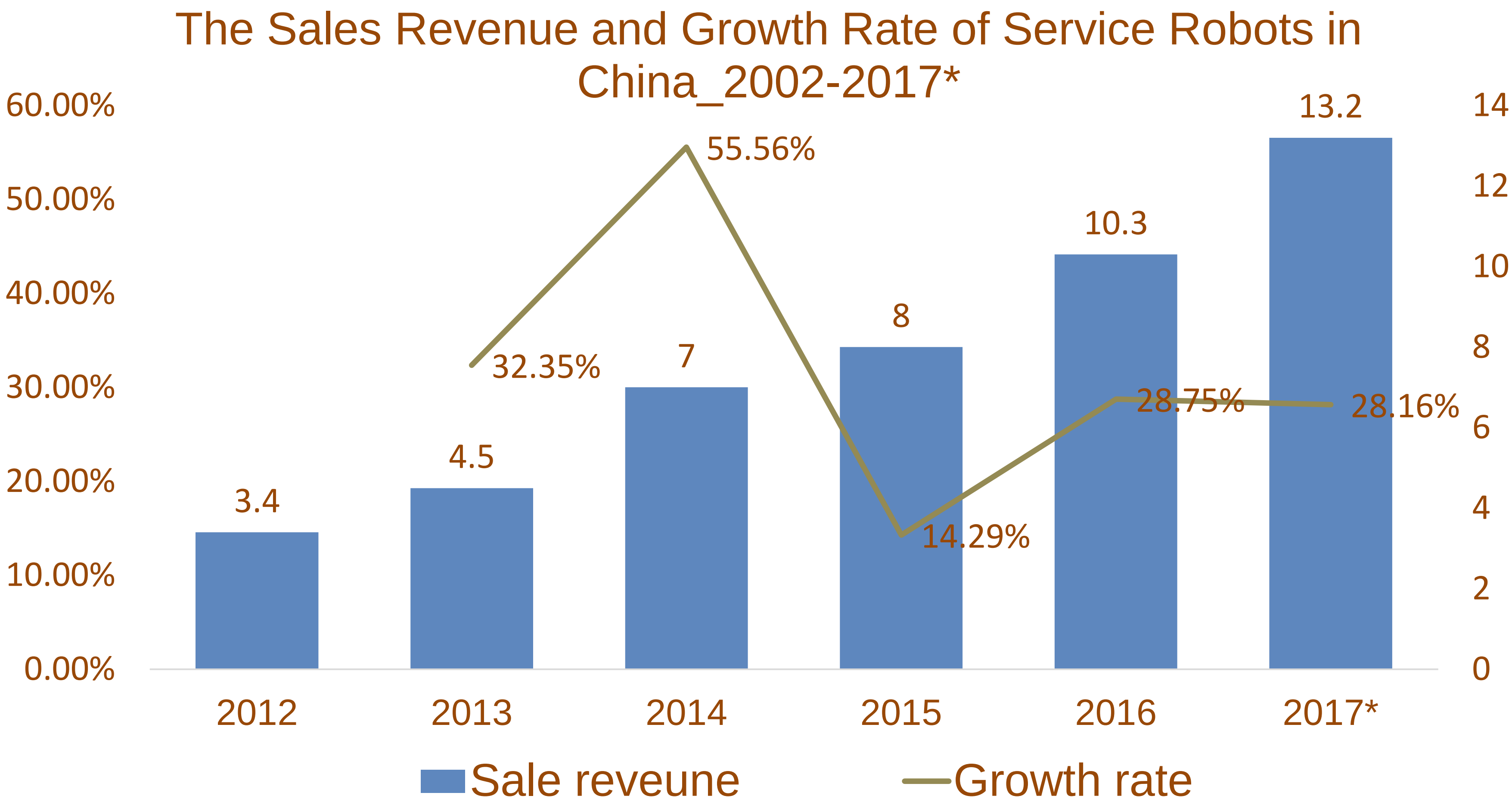
The Sales Revenue and Growth Rate of Industrial Robots in China_2002-2017*



Note: * is estimated value

Source: 2017 Chinese Robotic Industry Development Report

The Sales Revenue and Growth Rate of Service Robots in China_2002-2017*



Note: * is estimated value

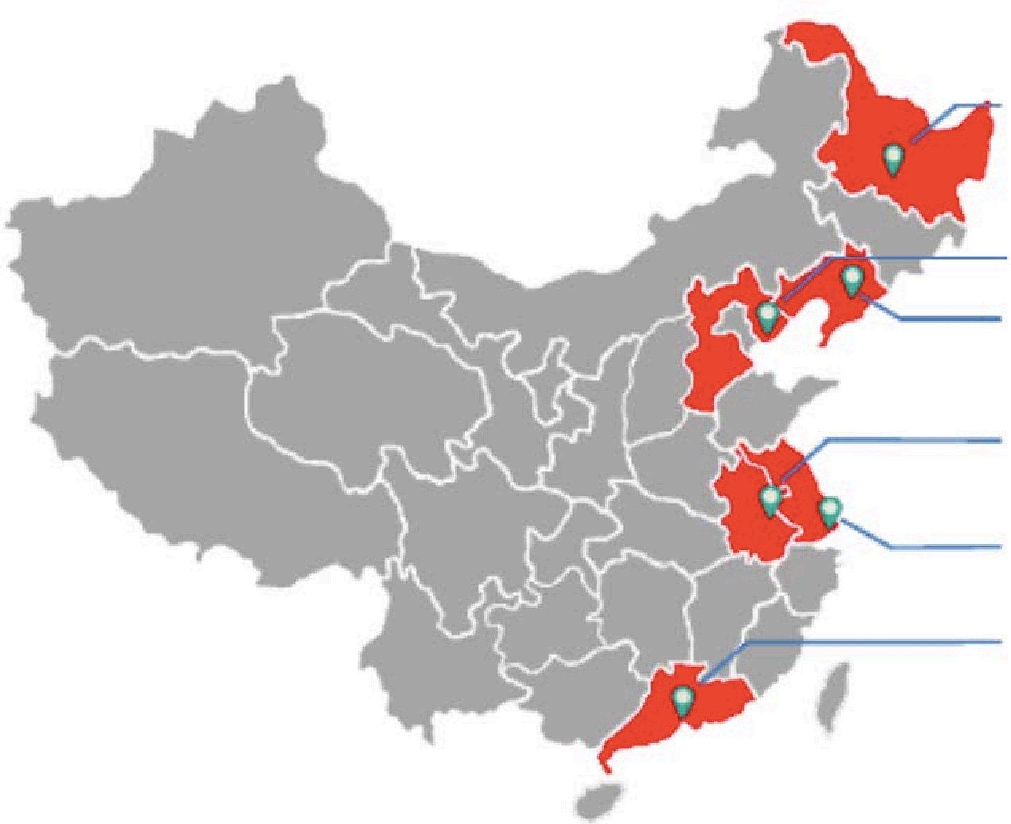
Source: 2017 Chinese Robotic Industry Development Report

The First Echelon Leading companies

Industrial Robot	Service Robot			Special Robot
	Households	Medical	Public service	
新松 SIASUN	科沃斯 ECOVRCS	妙手机器人 Smart Robot Technology Group	优必选 UBTECH	中信重工 开城 智能 CITI Heavy Industries
新时达 STEP	康利优蓝 CANBOT	博实股份 BOSHI	大疆 dji	视讯 GQY
云南昆船 Kunchuan Company	优必选 UBTECH	天智航 TINAVI Medical Technologies	怡丰 yeefung	新松 SIASUN
北京机科 Machinery Technology Development	ROOBO	钱璟 Qianjing Rehabilitation	捷通华声 sinoVoic	海伦哲 Xuzhou Handler Special

Source: 2017 Chinese Robotic Industry Development Report, Chinese Institute of Electronics

Selected Special Robotic Industry Park



Haerbin technology and innovation robotic industry park

Tangshan robotic industry park

Shenyang Huinan intelligence industry park

Wuhu robotic industry park

Kunshan Gaoxin district robotic industry park

Songshan lake robotic industry park

Source: 2017 Chinese Robotic Industry Development Report, Chinese Institute of Electronics

The Likely Winners of Robot Expansion and ICT Are

- **Medium term: Germany, France, Switzerland, Korea, Japan, USA, China, Singapore, Malaysia, Russia**
- **In the long run** software beats hardware; software is more flexible – here the **US is the leading economy and China might become No. 2**
  - **Winner 1 is pure market economy**
  - **Winner 2 is authoritarian system**
- **EU is too slow for effectively dealing with digital progress** – with present institutional setting and EU Commission too inefficient;EU&Eurozone budget too small
- **EU has adopted digital** modernization programme
- **Main driver of global dynamics is US/Trump with protectionist policy** that will undermine globalization and global stability: aggressive trade policy coupled with contradictory policy (raises US CA deficit= pushing US towards ++protectionism)

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Prospects for EU

EU is weakened through **BREXIT** 2019 (if it comes);

Italy: Popul. Gov

Digital gap EU; but logistics & trade opportunity unique: EU-China; partly landbased

EU could reinforce Digital EU integration and internat.networking of regional integration clubs

Eurozone reforms & EU Social Market Economy

In EU/G20 creating Digital Property Rights = Incentive to invest more in Data Security = productivity & stability gains

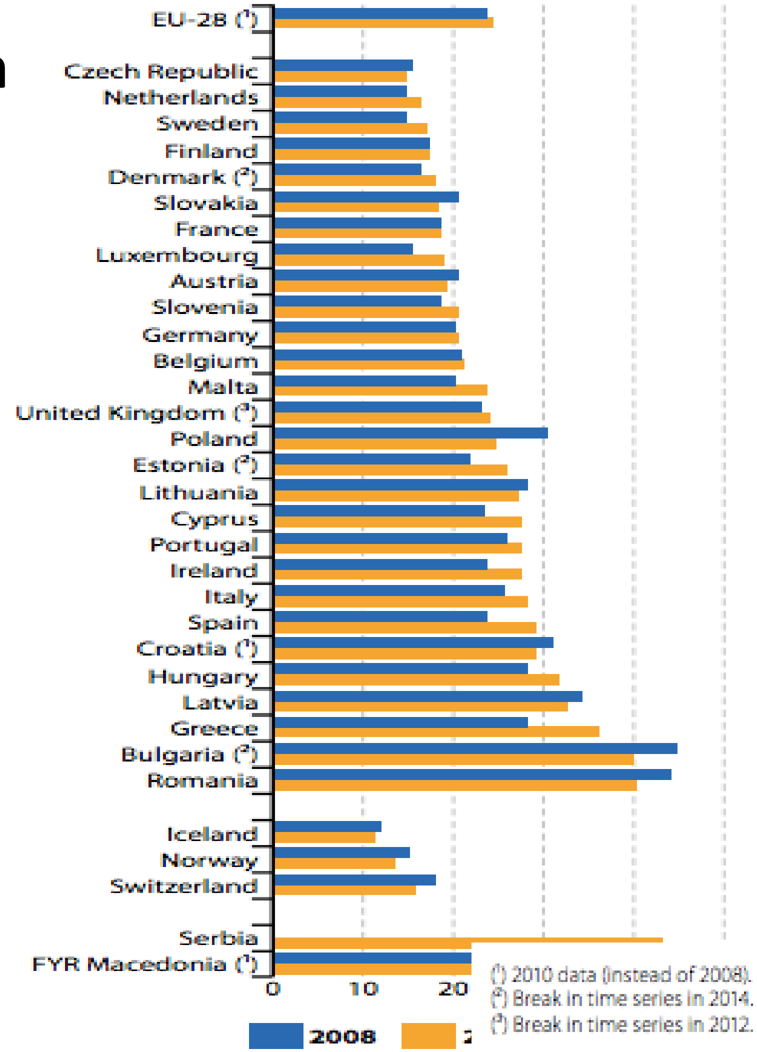
Continued support for Globalization: If more active labor market pol.; compen-sation of glob losers

Medium Term Challenges

- **Leading Robot producer countries = good economic prospects**
- **Leading Robot user countries = good economic prospects**
- Germany with Industry4.0 (Internet of the Things) will be a leader in the EU; German government wants cooperation with China – and China will be an Asian leader in Robotics in 2025
- **Robots + ICT expansion** = **rising inequality in the world economy,** partly also through digital financial globalization
- **Income from abroad increasinly non-taxed**(Föllmi on Switzerland) **=** contributing to a rising income share of superrich 1% in society(Pickety)
- Social Market Economy (EU type system) **could deal with challenges**
  - If more international cooperation in taxation **or more effective stronger regional integration;eg Eurozone with better tax system**
  - If government's social policy remains well focussed and limited – plus higher exp. on lifelong education; ***thus allows growth to continue***
  - **If EU27/28 cooperates more strongly with Asia/China;** China has strong political preference to cooperate with Germany – for historical reasons/M&E as well as focus on big German market & machinery & equipment industry

Figure 5.3: People at risk of poverty or social exclusion, by country, 2008 and 2014 (% of population)

Risk of new populism is rising as poverty risk high and rising
In many countries (e.g. Italy, UK, US);
& as US-EU28-China have not approach for consistent cooperation;
digital progress ok,
But rising inequality
In OECD countries
& new trade conflicts
=new instability
(BREXIT)



Source: Eurostat Statistical Books 2016 p.142; Smarter, greener, more inclusive? Indicators to support the Europe 2020 strategy-2016 edition.
Access: http://ec.europa.eu/eurostat/documents/3217494/7566774/KS-EZ-16-001-EN-N.pdf
Online data code: t2020_50

An Accidental BREXIT: London, Palgrave Macmillan 2017

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Many thanks for your kind attention

- www.eiiw.eu

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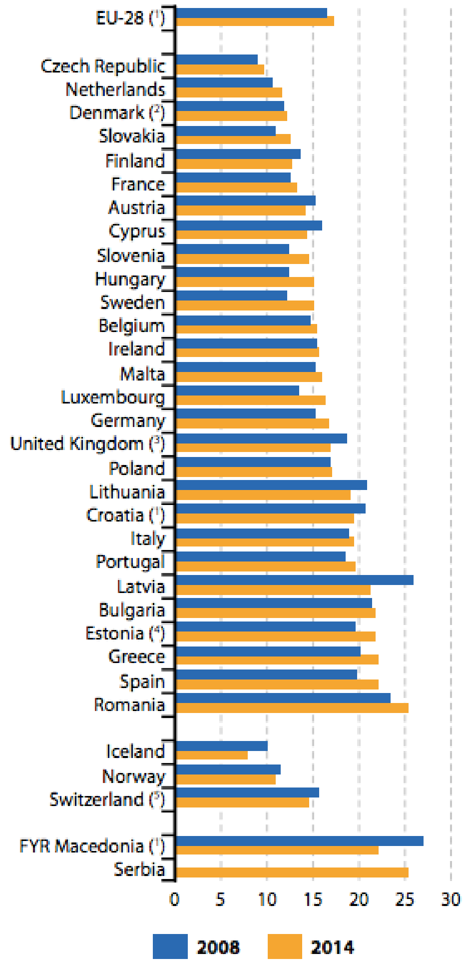
Potential Problems – New Perspectives

- **US powerful, but position unclear: If US follows Trump with Bilateralism** and aggressive trade policy Multilateral System – based on International Organizations –**globalization could collapse**; Europe/World back into a 19th century system of nationalist rivalries
- **Trump & BREXIT puts pressure on EU to reform** – unclear whether or not adequate reforms will be adopted. **BREXIT weakens Europe/the EU**
- **Trump trade policy could undermine economic growth and stability**
- **WTO and other international organizations are needed for digital growth and international stability**
- **Digital progress should be easier to absorb if there is**
  - ***Adequate institutional reforms***
  - ***Comprehensive re-training and education: EU countries better than UK and the US (?)***

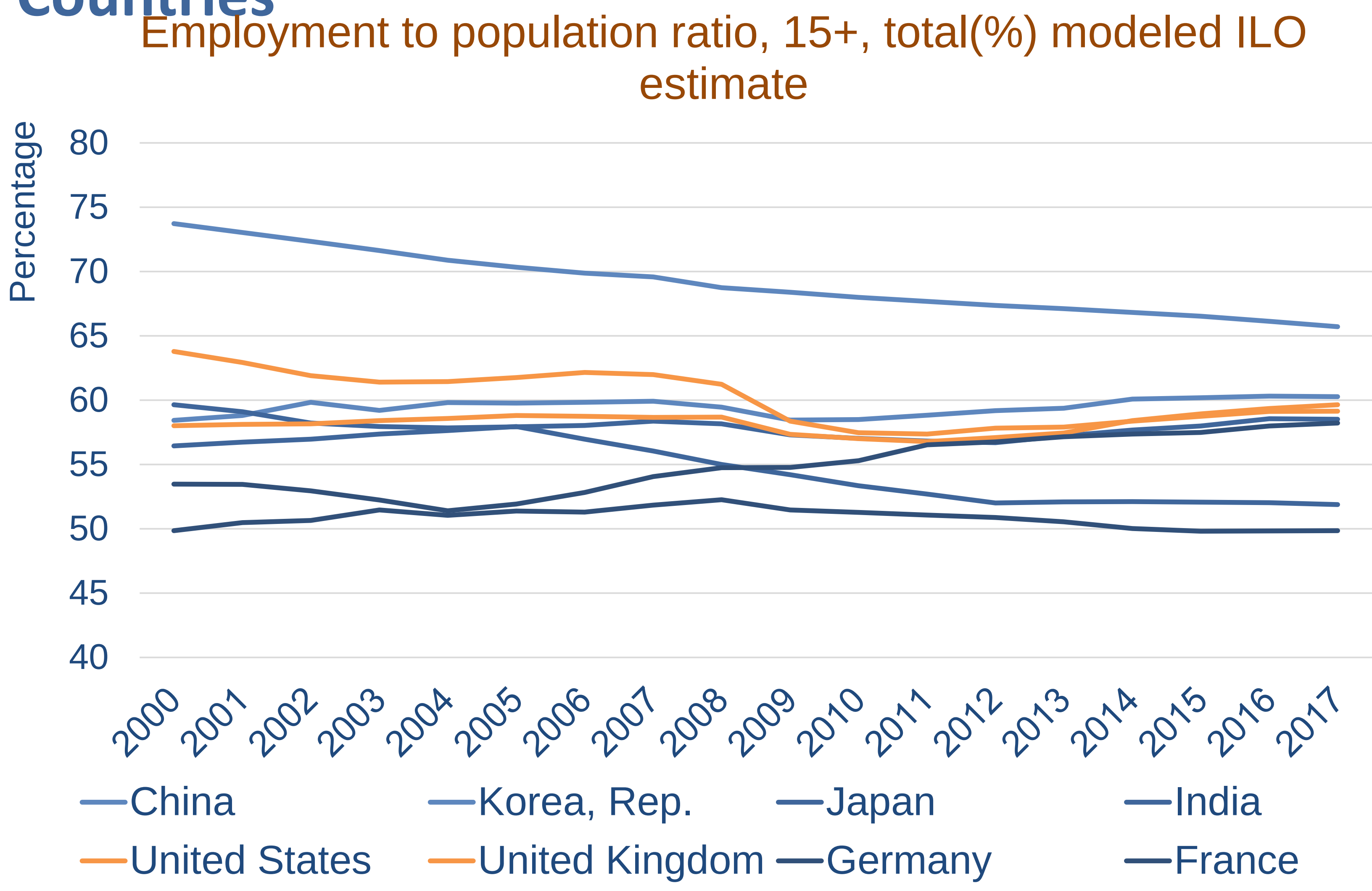
Figure 5.13: People at risk of poverty after social transfers, by country, 2008 and 2014 (% of population)



(1) 2010 data (instead of 2008).
(2) break in time series in 2013.
(3) break in time series in 2012.
(4) break in time series in 2014.
(5) 2013 data (instead of 2014).

Source: Eurostat Statistical Books 2016 p.155; Smarter, greener, more inclusive? Indicators to support the Europe 2020 strategy-2016 edition.
Access: http://ec.europa.eu/eurostat/documents/3217494/7566774/KS-EZ-16-001-EN-N.pdf
Online data code: t2020_55

Employment to Population ratio for Selected Countries



Source: World Bank

Appendix: Nicht-EU-Zuwanderer-Armutsrisiko rel. hoch: EU-Einwanderungsgesetz – wegen Binnenmarkt – nötig als Rahmen; plus nationale Integrationsgesetze

Abb. Zum Armutsrisiko in europäischenLändern (Europa2020, 2016e)

*Grün=Nicht-EU-Zuwanderer: erkennbar nötig, dass hier Verbes-serung kooperativ o. via EU-Ergänzungspol.

- Blau=EU-Zuwanderer
- Orange = Einheimische

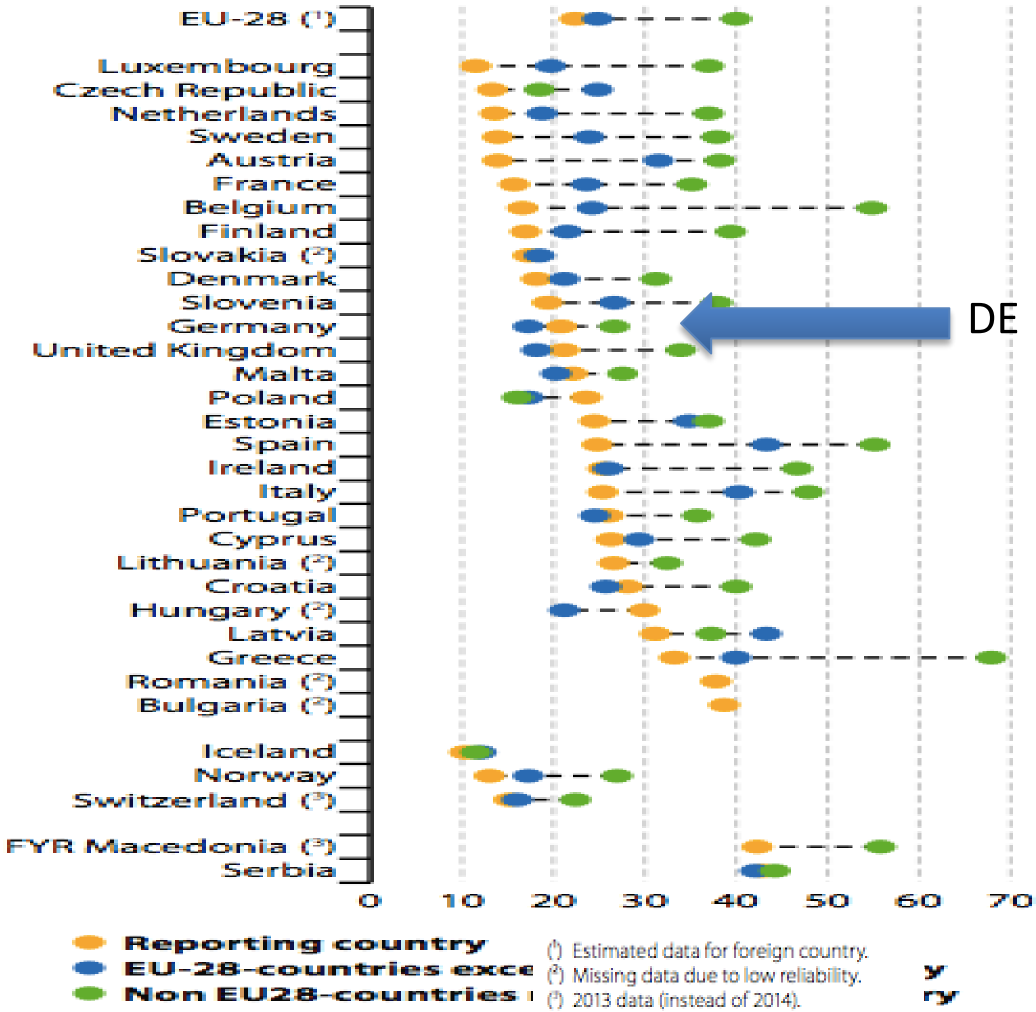


Figure 5.9: People at risk of poverty or social exclusion by group of country of birth, by country, 2014 (% of population aged 18 and over)

Source: Eurostat Statistical Books 2016 p.149; Smarter, greener, more inclusive? Indicators to support the Europe 2020 strategy-2016 edition.
Access: http://ec.europa.eu/eurostat/documents/3217494/7566774/KS-EZ-16-001-EN-N.pdf
Online data code: t2020_149

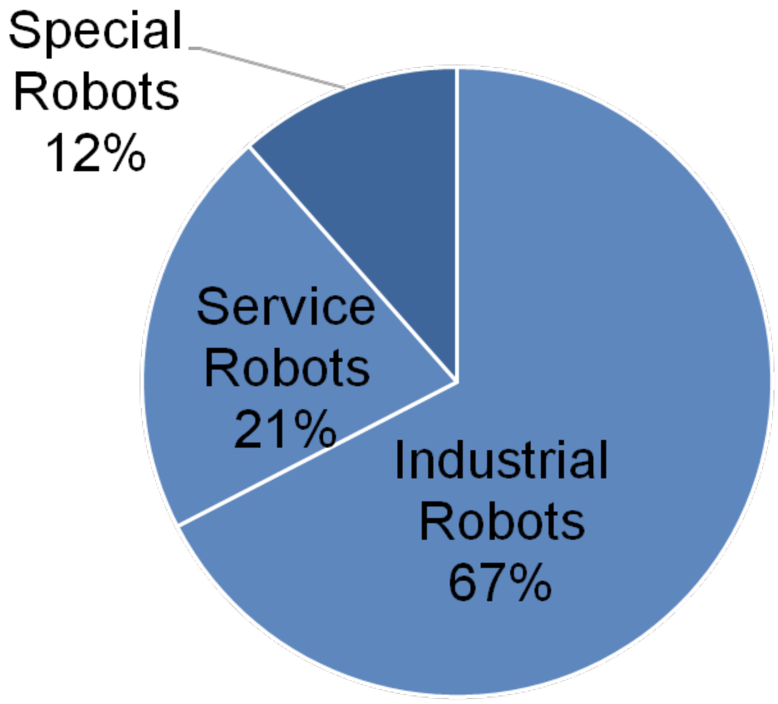
Applications for Patents for Inventions and Utility Models according to the section of IPC in China from 2002 to 2015

（sectoral share in percentage）

Classification / Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total growth rate 2015/2002
A-H Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Section A Human necessities	20.50%	18.90%	19.30%	19.40%	19.90%	19.10%	18.00%	16.70%	18.00%	17.40%	17.00%	16.90%	19.20%	19.10%	**-6.83%**
Section B Performing operation: Transportation	22.60%	20.80%	18.50%	18.80%	19.40%	20.50%	19.20%	20.40%	21.90%	22.40%	24.20%	25.50%	23.00%	25.00%	**10.62%**
Section C Chemistry; Metallurgy	7.40%	8.50%	10.30%	10.80%	9.70%	8.50%	6.80%	7.30%	6.60%	7.80%	7.80%	7.80%	10.00%	10.00%	**35.14%**
Section D Textiles; Papers	2.10%	1.80%	1.80%	1.80%	1.90%	2.00%	1.70%	1.60%	1.90%	2.00%	1.90%	1.70%	1.70%	1.60%	**-23.81%**
Section E Fixed constructions	8.00%	7.50%	6.70%	6.80%	7.00%	6.80%	6.40%	5.90%	6.70%	6.40%	6.50%	6.80%	5.60%	5.90%	**-26.25%**
Section F Mechanical engineering	15.10%	14.10%	12.20%	11.70%	12.80%	14.20%	13.80%	13.40%	13.80%	13.30%	13.40%	13.40%	11.10%	11.20%	**-25.83%**
Section G Physics	11.30%	13.50%	14.10%	13.90%	14.00%	13.70%	15.90%	15.40%	13.90%	13.80%	13.50%	13.30%	15.00%	14.30%	**26.55%**
Section H Electricity	13.00%	15.00%	17.10%	16.80%	15.30%	15.20%	18.10%	19.30%	17.20%	16.90%	15.80%	14.60%	14.20%	12.90%	**-0.77%**

Source: SIPO

The Robots Market Scale in China_2017



	The Robots Market Scale in China_ 2017 (100 million USD)
Industrial Robots	42.2
Service Robots	13.2
Special Robots	7.2

Source: 2017 Chinese Robotic Industry Development Report, Chinese Institute of Electronics

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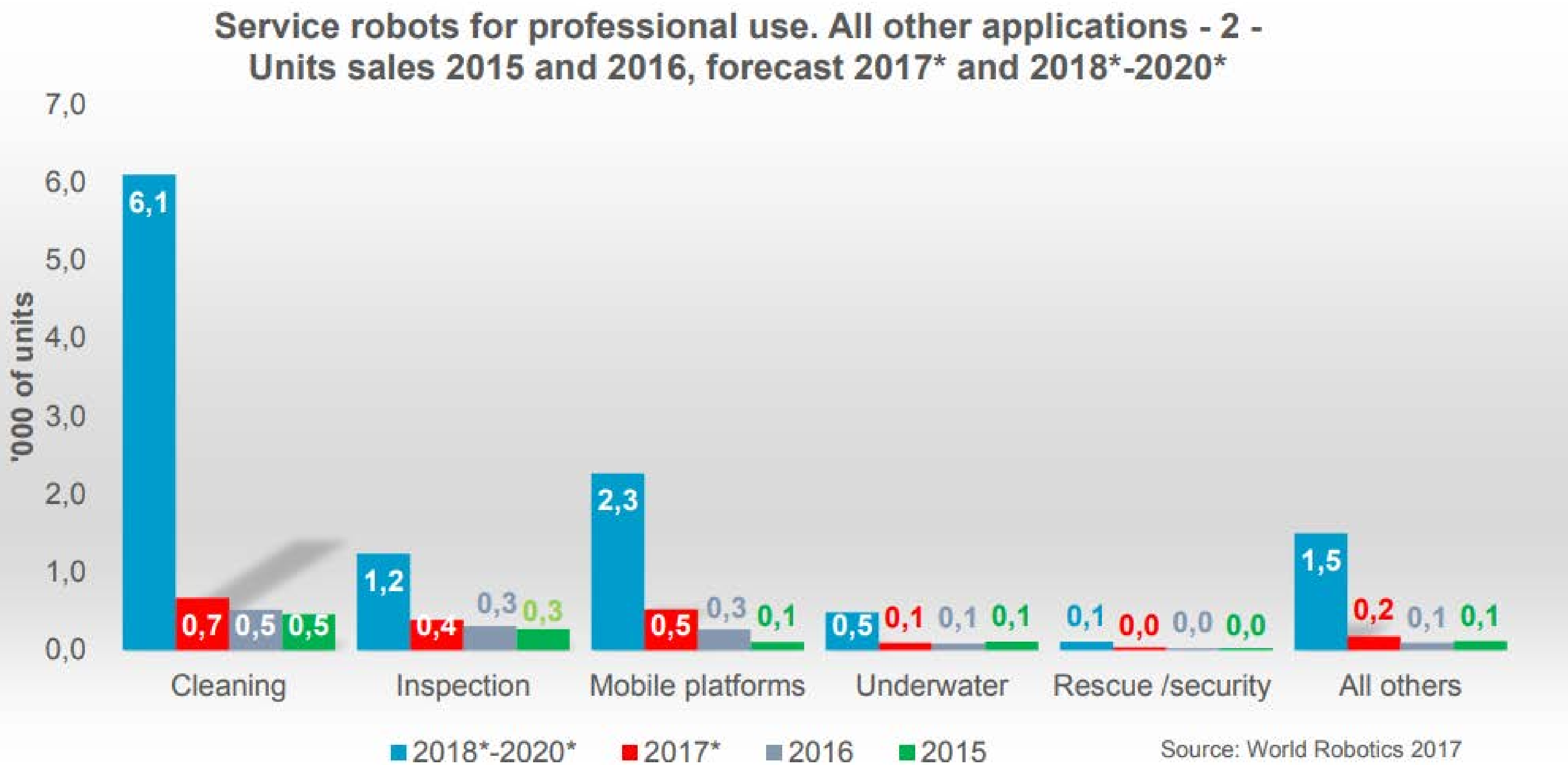

*forecast

Source: World Robotics 2017

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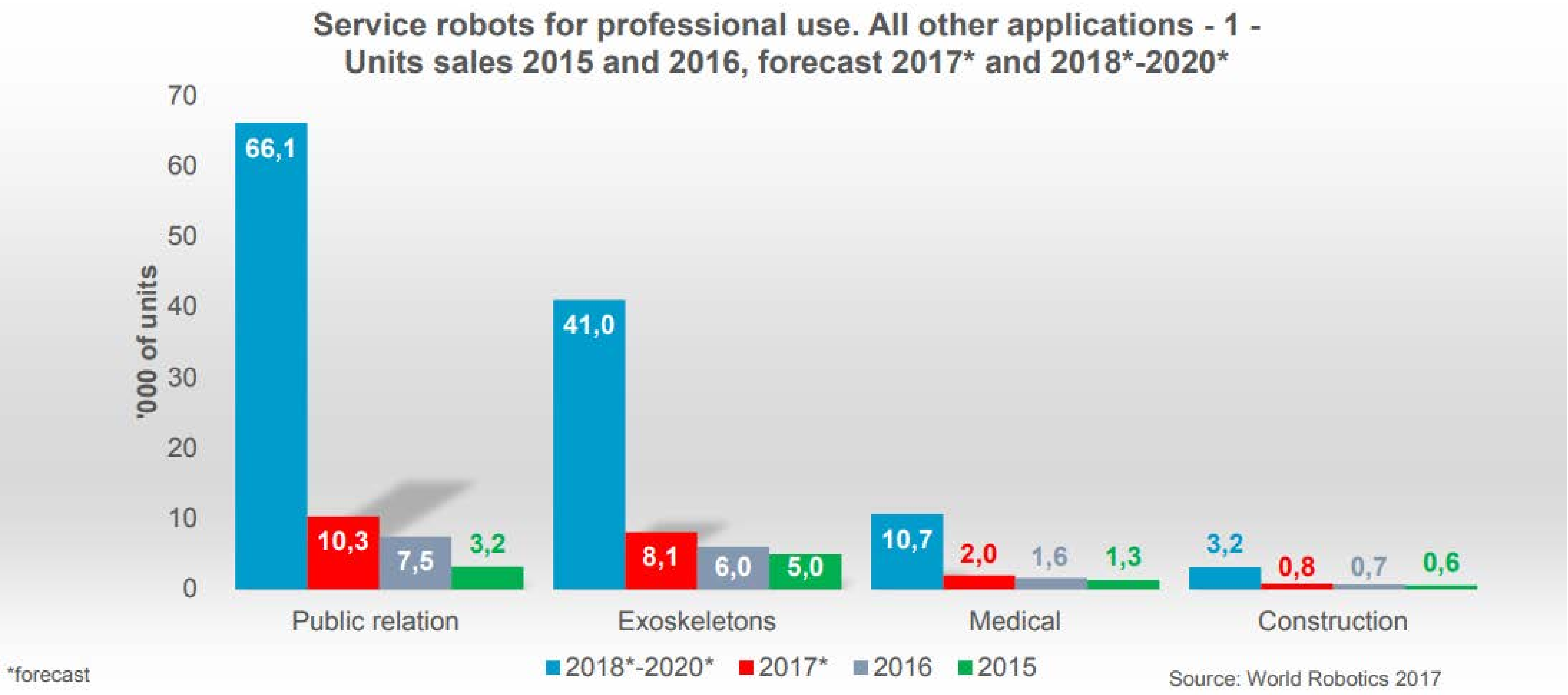
Service robots for professional use. All other applications - 1 -
Units sales 2015 and 2016, forecast 2017* and 2018*-2020*
'000 of units
70
60
50
40
30
20
10
0
66,1
10,3
7,5
3,2
41,0
8,1
6,0
5,0
10,7
2,0
1,6
1,3
3,2
0,8
0,7
0,6
Public relation
Exoskeletons
Medical
Construction
2018*-2020*
2017*
2016
2015
*forecast
Source: World Robotics 2017

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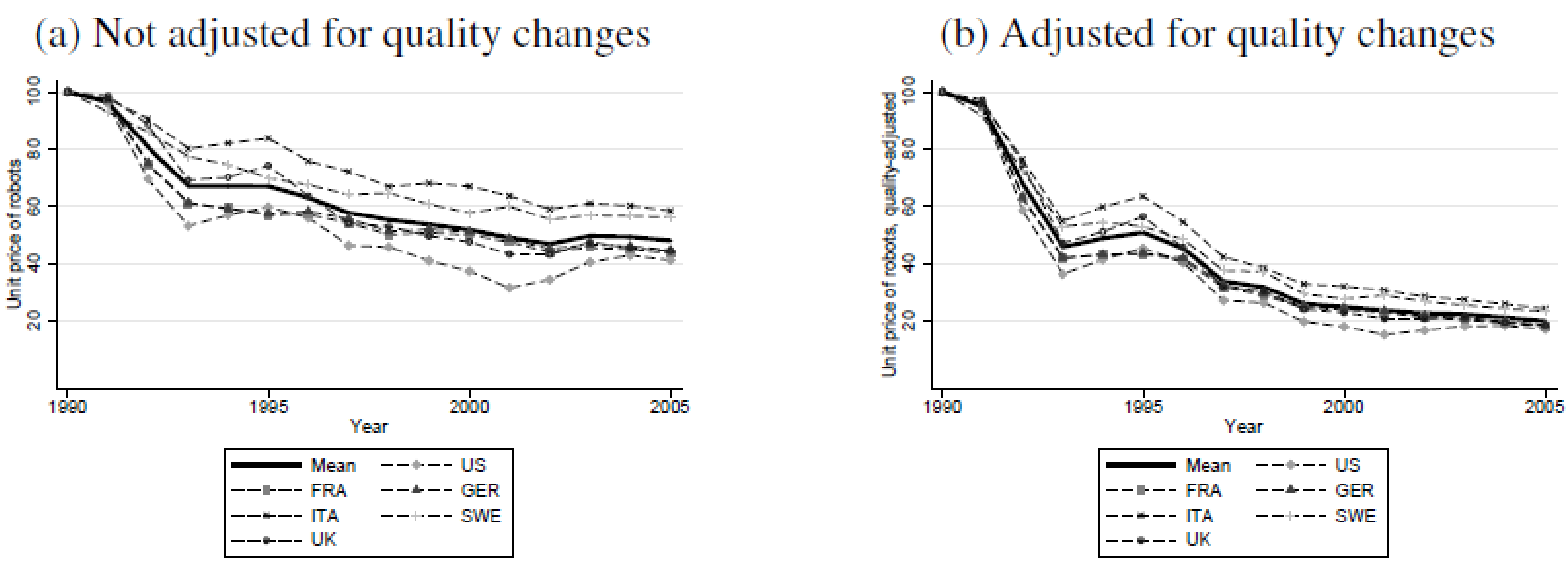
Relative price of robots falling= incentive to invest more in Robots

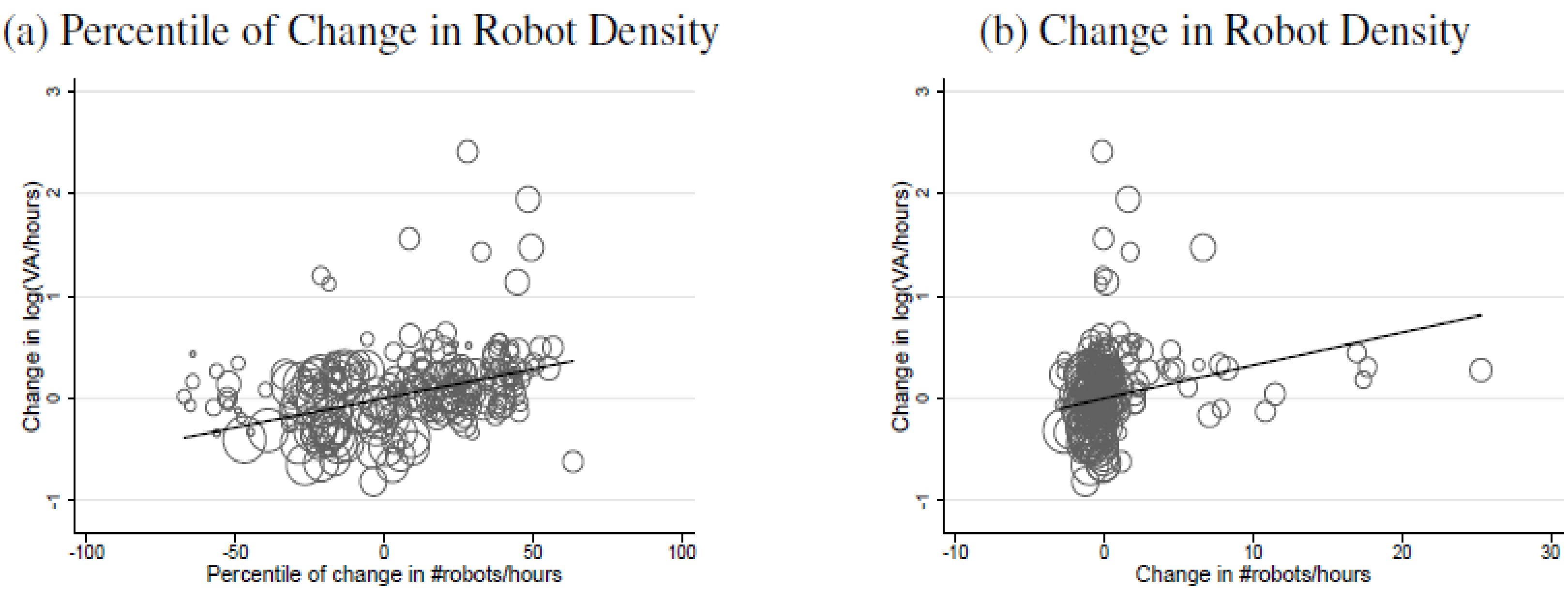
Figure 1: The Price of Robots in Six Countries 1990-2005



Graetz, Georg/Guy, Michaels: (2015), Robots at work. CEP Discussion Paper No 1335. http://www.sherpa-robotics.com/wp-content/uploads/2017/11/Robots_at-_Work.pdf

Productivity and Robotics=Dynamic field=Slightly pos. correlated; however, product differentiation is the key element/innovations= higher profits for robotics-using firms

Figure 2: Growth of Productivity and Robots 1993-2007



Graetz, Georg/Guy, Michaels: (2015), Robots at work. CEP Discussion Paper No 1335. http://www.sherpa-robotics.com/wp-content/uploads/2017/11/Robots_at-_Work.pdf

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Table 1: *Descriptive statistics*

	# Obs.	Mean	Standard deviation	Min	Max	Change (mean)	Change (SD)
Dependent variables							
Employment rate [1)]	111	0.480	0.080	0.319	0.686	0.046	0.048
Employment rate (15-64)	111	0.583	0.091	0.382	0.768	0.077	0.053
Gross nominal hourly wages	1780	9.469	4.900	0.054	35.707	3.647	4.601
Gross nominal weekly wages	1780	349.955	183.948	2.143	1328.583	98.059	157.321
Variables of interest							
Industrial robots per 1000 workers	113	1.562	1.502	0.000	7.236	3.252	2.828
IT capital per 1000 workers [2)]	92	1.346	0.372	0.402	2.224	1.770	1.603
Control variables							
Population (in million)	107	2.227	1.829	0.025	10.900		
working age population (share)	104	0.817	0.048	0.679	0.894		
Medium and high education (share)	111	0.517	0.193	0.198	0.746		
Manufacturing employment (share)	108	0.209	0.072	0.043	0.365		
Routinization Index	101	0.189	0.134	-0.077	0.512		
Offshoring Index	101	0.058	0.084	-0.126	0.294		
Δ exposure to Chinese imports	92	0.00009	0.00007	0.00000	0.00041		
Δ exposure to US imports	92	-0.00005	0.00009	-0.00066	0.00008		

Note: values are presented at 1995 level; changes between 1995 and 2007, wage data based on demographic cell structure
1) employed individuals divided by population older than 15 2) in milllion Euros

Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 16.

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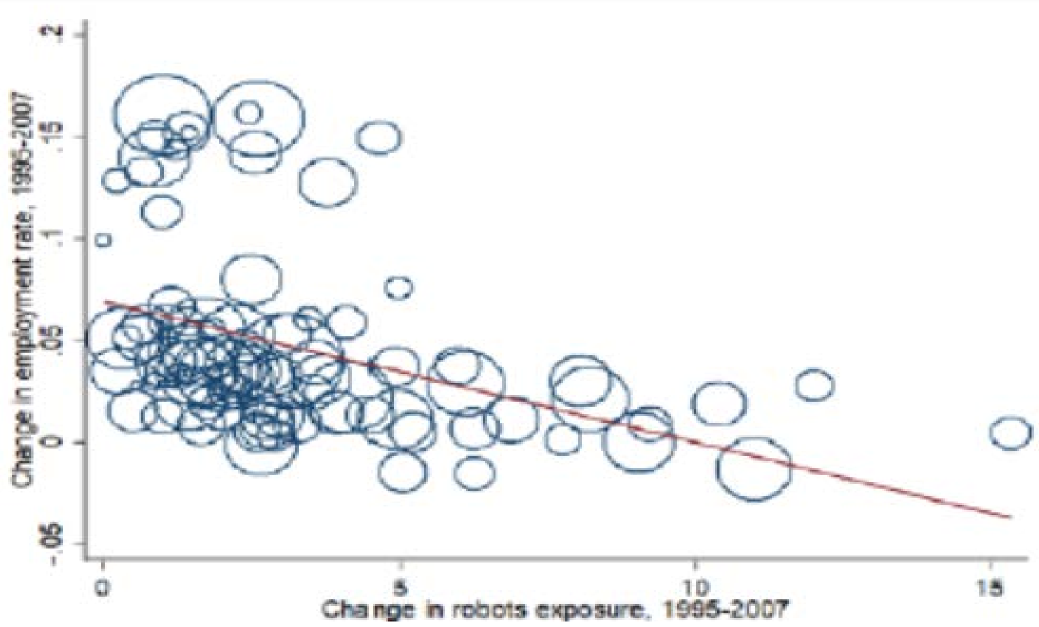
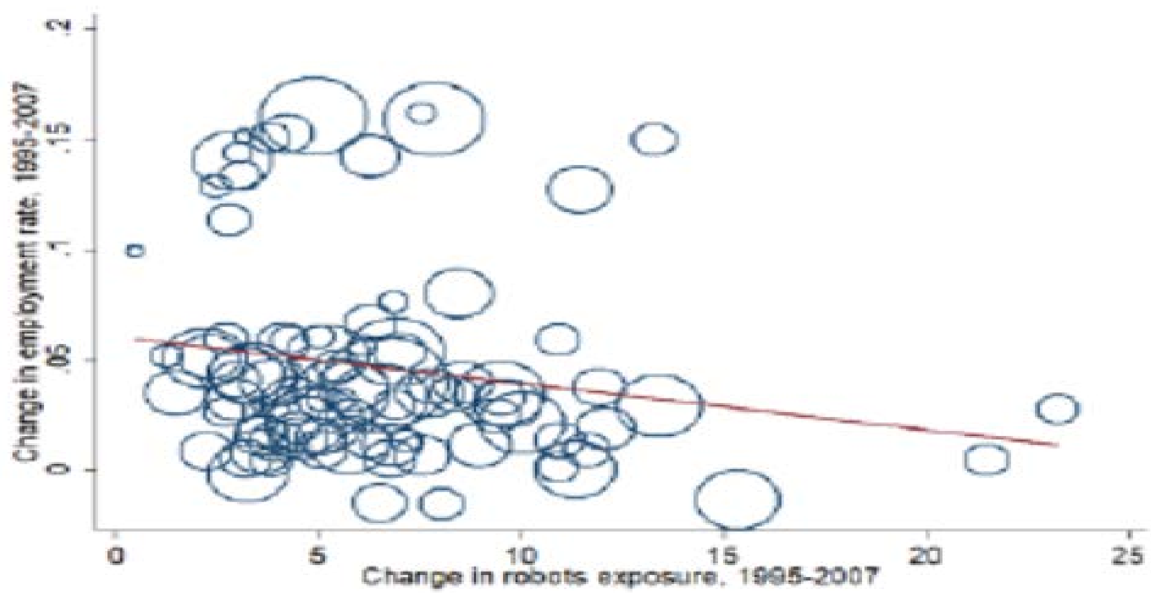
Figure 12a: Change in exposure to robots and in employment rate – Total economy (Change in percentage points)



Source: Calculations based on IFR, Eurostat, EU Klems.
Note: Circles represent relative size (working age population) of each of the NUTS2 regions considered.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 17.

Figure 12b: Change in exposure to robots and in employment rate – Industry

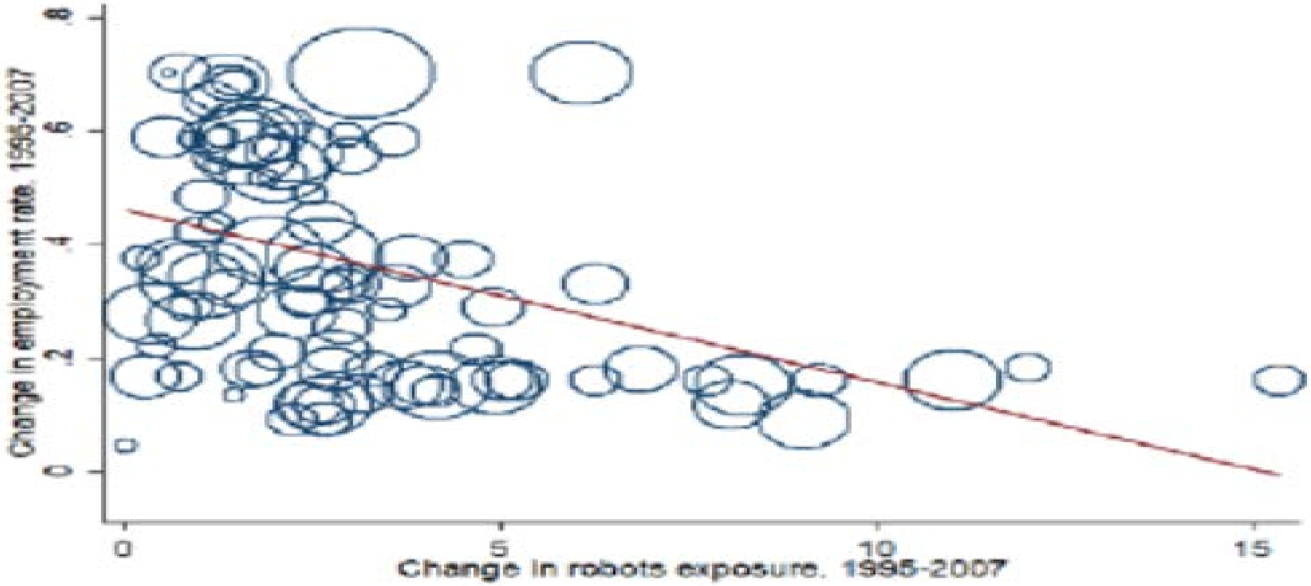
(Change in percentage points)



Source: Estimation based on sample as described in Section 2.4.
Note: Circles represent relative size (working age population) each of the NUTS2 regions considered.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 17.

Figure 13a: Change in exposure to robots and in log hourly wages – Total economy

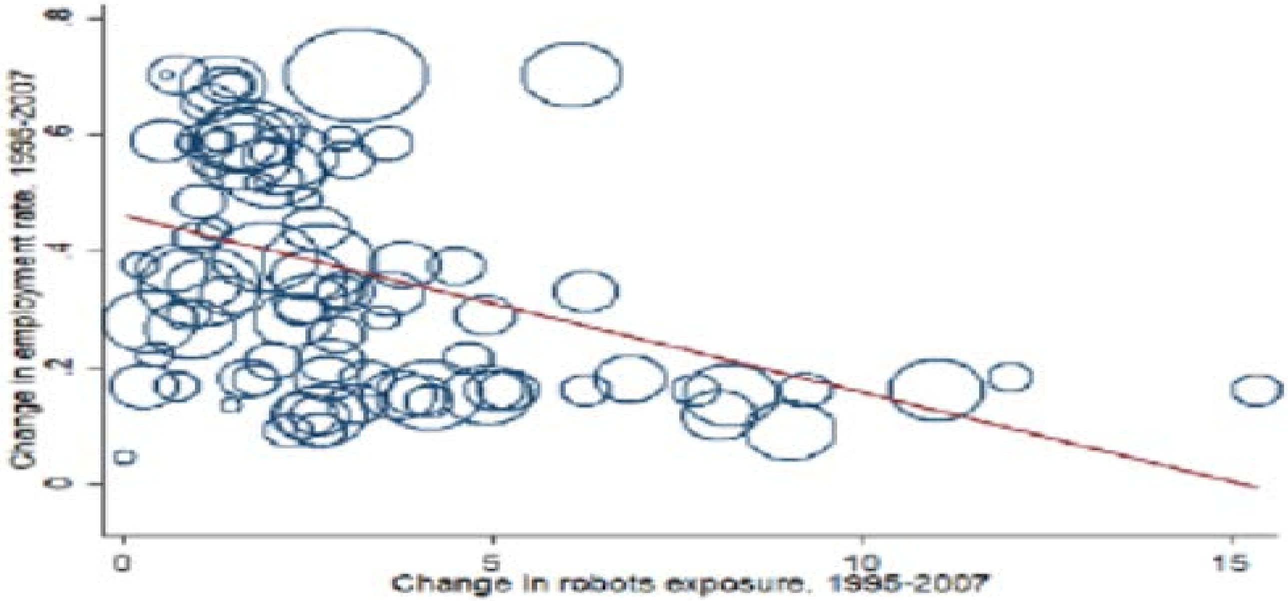
(Change in percentage points)



Source: Calculations based on IFR, Eurostat, EU Klems.
Note: Circles represent relative size (working age population) of each of the NUTS2 regions considered.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 17.

Figure 13b: Change in exposure to robots and in log hourly wages – Industry

(Change in percentage points)



Source: Estimation based on sample as described in Section 2.4.
Note: Circles represent relative size (working age population) of each of the NUTS2 regions considered.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 17.

Table 2: Impact on employment for Total Economy

	(1) Employment rate	(2) Employment rate	(3) Employment rate	(4) Employment rate	(5) Employment rate	(6) Employment rate	(7) Employment rate	(8) Employment rate
Change in exposure to robots (1995-2007)	-0.0045	-0.0031***	-0.0016***	-0.0016***	-0.0027***	-0.0026***	-0.0016***	-0.0020*
	(0.0039)	(0.0010)	(0.0005)	(0.0005)	(0.0009)	-0.0007	[-0.0018, -0.0011]	[-0.0104, -0.0002]
North dummy		V	V	V	V	V	V	V
Demographics			V	V	V	V	V	V
Broad manufacturing share				V	V	V	V	V
Routinization, offshoring, import exposure					V	V	V	V
Change in exposure to IT capital (1995-2007)						V	V	V
Instruments	-	-	-	-	-	-	UK and DK robot exposure, EPL in 1990	UK and DK robot exposure, ΔEPL 1985-2007
Observations	1,382	1,382	1,308	1,292	1,129	1,129	1,129	1,129
R-squared	0.1819	0.2334	0.3389	0.3461	0.3551	0.2008	0.1999	0.2005

Wild cluster bootstrapped standard errors in parentheses; WRE 90% confidence intervals in square brackets. Data in demografic cells.

*** p<0.01, ** p<0.05, * p<0.10

Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 19.

***Table 3**: Impact of exposure to robots and IT capital on employment - Total Economy*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Employment rate	Employment rate	Employment rate	Employment rate	Employment rate	Employment rate	Employment rate
Change in exposure to robots (1995-2007)	-0.0012	-0.0017	-0.0020*	-0.0021***	-0.0026***	-0.0016***	-0.0020*
	(0.0018)	(0.0015)	(0.0011)	(0.0007)	(0.0008)	[-0.0018, -0.0011]	[-0.0104, -0.0002]
Change in exposure to IT capital (1995-2007)	0.0175***	0.0193***	0.0217***	0.0219***	0.0231	0.0231**	0.0231***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0153)	[0.0052,0.0315]	[0.0072,0.0312]
North dummy		V	V	V	V	V	V
Demographics			V	V	V	V	V
Broad manufacturing share				V	V	V	V
Routinization, offshoring, import exposure					V	V	V
Instruments	-	-	-	-	-	UK and DK robot exposure, EPL in 1990	UK and DK robot exposure, ΔEPL 1985-2007
Observations	1,382	1,382	1,308	1,292	1,129	1,129	1,129
R-squared	0.1541	0.1582	0.1787	0.1795	0.2008	0.3547	0.3552

Wild cluster bootstrapped standard errors in parentheses; WRE 90% confidence intervals in square brackets. Data in demografic cells.

*** p<0.01, ** p<0.05, * p<0.10

Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 19.

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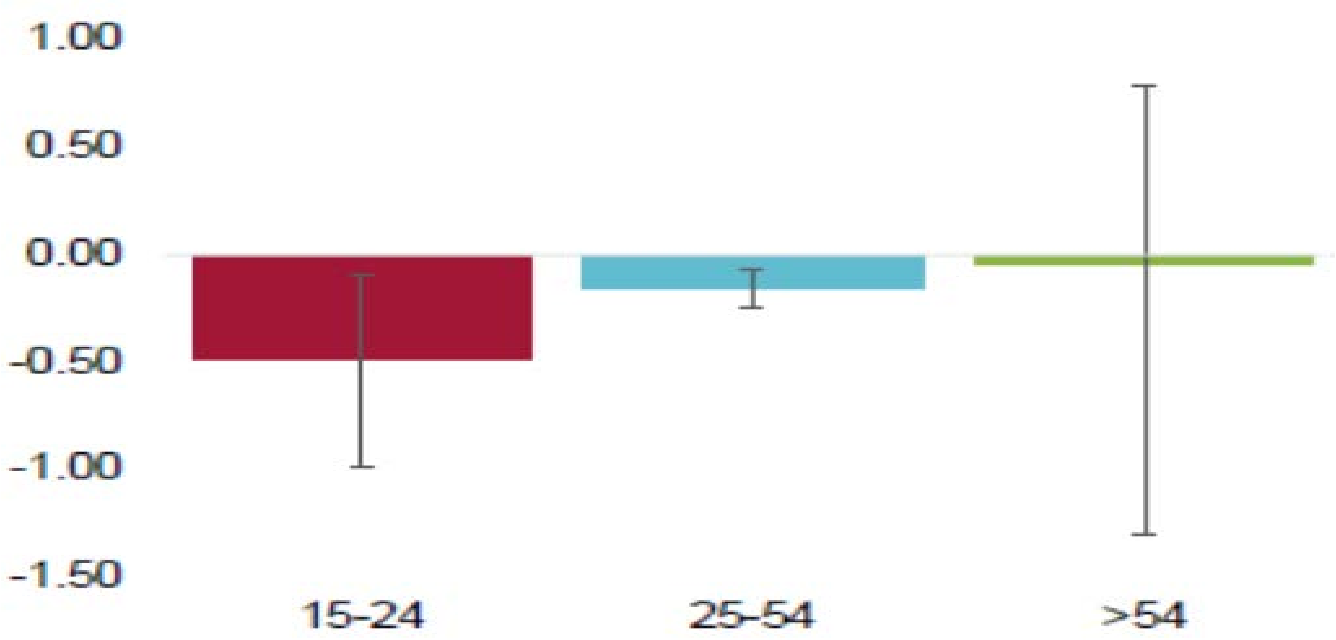
Figure 14a: Employment effects of exposure to robots by age group

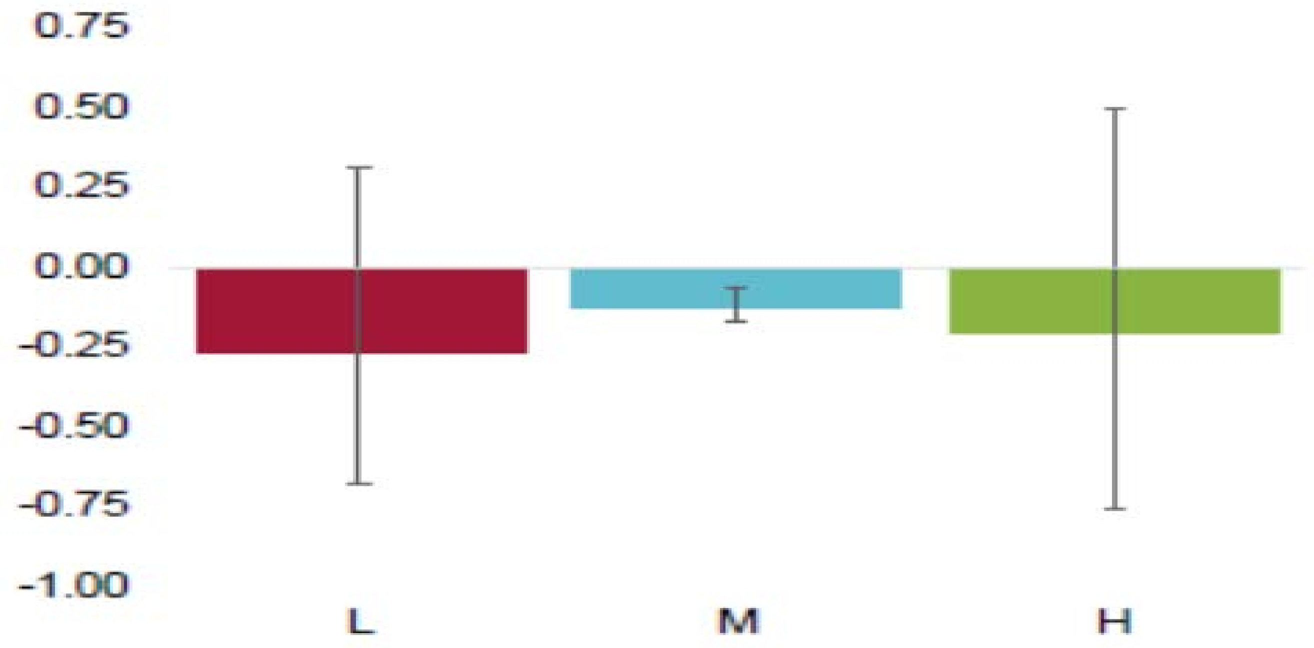
(Change in employment rate from 1 more robot per 1000 workers in the economy, in p.p.)



Note: Estimates based on full specification and 2SLS; WRE 90% confidence intervals.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 20.

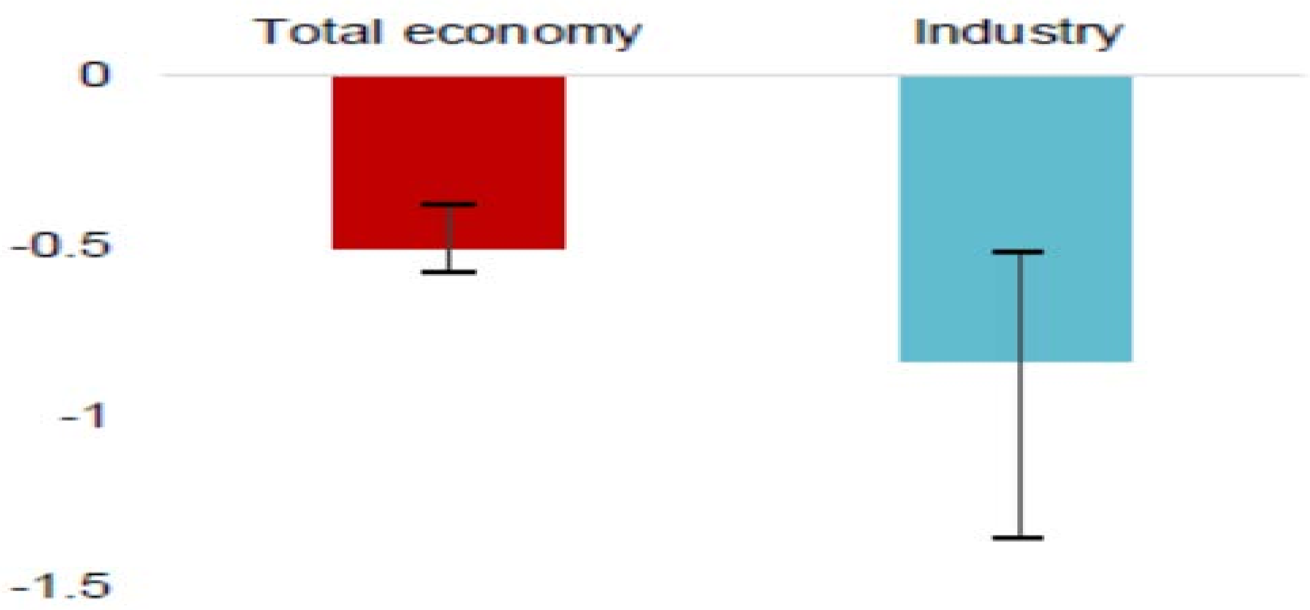
Figure 14b: Employment effects of exposure to robots by education group

(Change in employment rate from 1 more robot per 1000 workers in the economy, in p.p.)



Note: Estimates based on full specification and 2SLS; WRE 90% confidence intervals.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 20.

Figure 15a: Cumulative employment effects of exposure to robots in industry and total economy (Change in employment rate from the observed change in robots per 1000 workers, in p.p.)

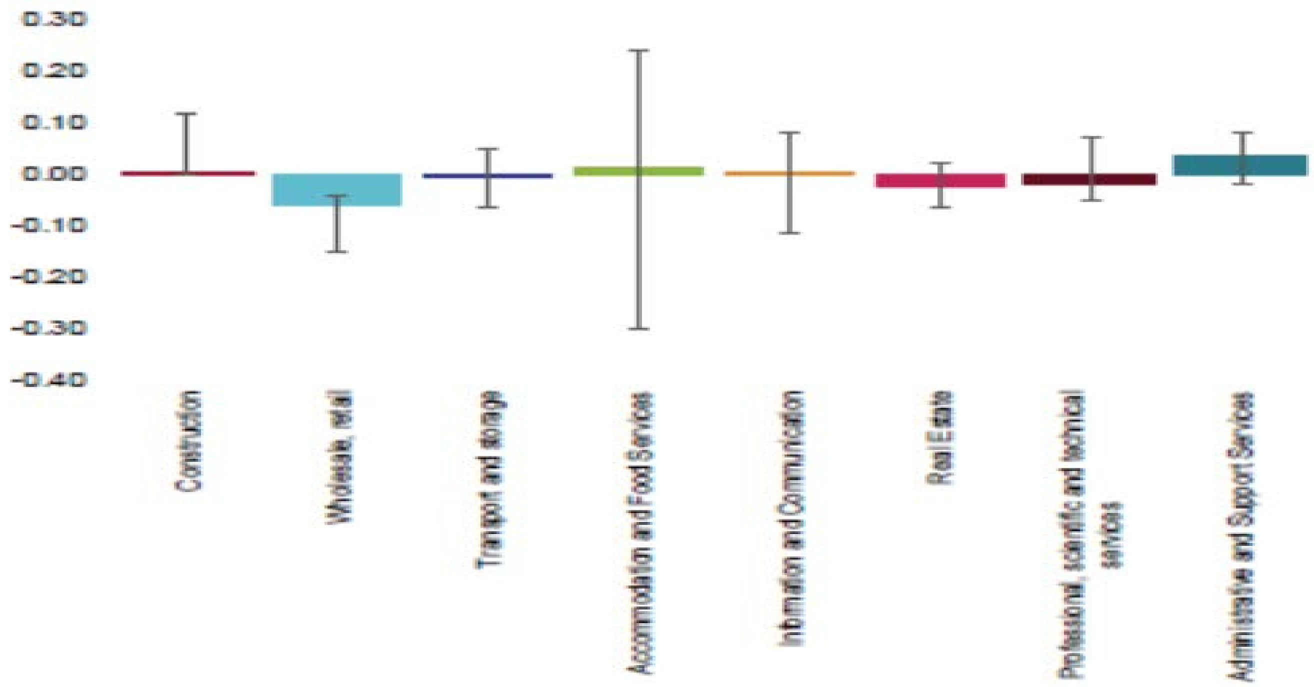


Note: Estimates based on full specification and 2SLS (Table 2, column 7, and Table A1, column 4, respectively); WRE 90% confidence intervals.

Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 20.

Figure 15b: Employment effects of exposure to robots by education group

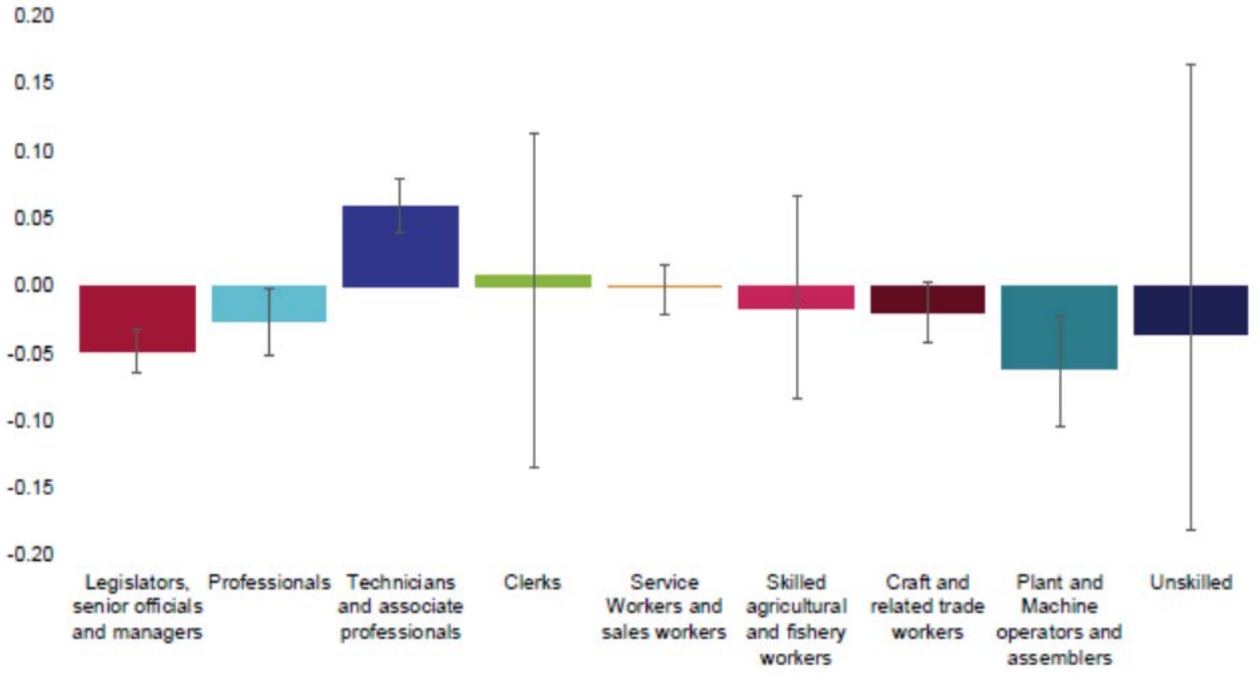
(Change in employment rate from 1 more robot per 1000 workers, in p.p.)



Note: Estimates based on full specification and 2SLS; WRE 90% confidence intervals.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 21.

Figure 16: Employment effects of exposure to robots by occupation

(Change in employment rate from 1 more robot per 1000 workers in the economy, in p.p.)



Note: Estimates based on full specification and 2SLS; WRE 90% confidence intervals.
Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 21.

Table 4: Impact on wages - Total Economy

	(1) Hourly wages	(2) Hourly wages	(3) Hourly wages	(4) Hourly wages	(5) Hourly wages	(6) Hourly wages	(7) Hourly wages	(8) Hourly wages
Change in exposure to robots (1995-2007)	-0.0275***	-0.0144**	-0.0091	-0.0100	-0.0044	-0.0048	-0.0063*	-0.0139
	(0.0089)	(0.0073)	(0.0153)	(0.0274)	(0.0065)	(0.0072)	[-0.0460, -0.0080]	[-0.1732, 0.0372]
North dummy		V	V	V	V	V	V	V
Demographics			V	V	V	V	V	V
Broad manufacturing share				V	V	V	V	V
Routinization, offshoring, import exposure					V	V	V	V
Growth in IT capital					V	V	V	V
Instruments	-	-	-	-	-	-	UK and DK robot exposure, EPL in 1990	UK and DK robot exposure, ΔEPL 1995-2007
Observations	1,337	1,337	1,268	1,251	1,135	1,135	1,135	1135
R-squared	0.0738	0.1589	0.1672	0.1748	0.2620	0.2757	0.2756	0.2708

Wild cluster bootstrapped standard errors in parentheses, WRE 90% confidence intervals in square brackets. Data in demografic cells.

*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Note: Estimates based on full specification and 2SLS; WRE 90% confidence intervals.

Source: Chiacchio, Francesco; Petropoulos, Georgios; Pichler, David (2018), The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach, Bruegel Working Paper, 2, 18. April 2018, URL: http://bruegel.org/wp-content/uploads/2018/04/Working-Paper_02_2018.pdf. p. 22.

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Table 4: Dependent variable: ln(Employment); whole sample (2,404 observations)

	(1) POLS	(2) FE	(3) GMM-SYS
ln(Employment)$_{t-1}$	0.927***	0.651***	0.902***
	(0.007)	(0.036)	(0.034)
ln(Value added)	0.065***	0.072***	0.081***
	(0.007)	(0.010)	(0.024)
ln(Cost of labor per employee)	-0.189***	-0.422***	-0.236***
	(0.020)	(0.044)	(0.022)
ln(Investment in physical capital)$_{t-1}$	0.009***	0.009***	0.008
	(0.002)	(0.002)	(0.006)
ln(ETC)$_{t-1}$	-0.001	-0.001	-0.002
	(0.001)	(0.001)	(0.001)
ln(R&D)$_{t-2}$	0.002	0.002	0.004
	(0.001)	(0.002)	(0.003)
Time-dummies	Yes	Yes	Yes
Sectoral-dummies	Yes	No	Yes
Constant	0.265***	2.485***	0.386***
	(0.049)	(0.247)	(0.089)
Wald test time-dummies (p-value)	20.27*** (0.000)	17.10*** (0.000)	10.13*** (0.000)
Wald test sectoral-dummies (p-value)	4.39*** (0.000)	-	4.07*** (0.000)
R^2	0.99		
R^2 (within)		0.66	
AR(1) (p-value)			0.000***
AR(2) (p-value)			0.449
Hansen test $\chi^2(96)$ (p-value) (129 instruments)			0.653

Notes: -Robust standard errors in parentheses; -* significance at 10%, ** 5%, *** 1%.

Source:
IZA Institute of Labor Economics, 01.2017

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Table 5: Dependent variable: ln(Employment);
High-tech (684 observations) and Low-tech firms (1,720 observations)

	HIGH-TECH FIRMS			LOW-TECH FIRMS		
	(1) POLS	(2) FE	(3) GMM-SYS	(1) POLS	(2) FE	(3) GMM-SYS
ln(Employment) $_{t-1}$	0.925***	0.725***	0.878***	0.923***	0.590***	0.908***
	(0.015)	(0.048)	(0.029)	(0.007)	(0.047)	(0.033)
ln(Value added)	0.055***	0.045***	0.084***	0.072***	0.092***	0.087***
	(0.016)	(0.017)	(0.021)	(0.059)	(0.012)	(0.022)
ln(Cost of labor per employee)	-0.232***	-0.418***	-0.284***	-0.180***	-0.423***	-0.236***
	(0.057)	(0.078)	(0.061)	(0.018)	(0.054)	(0.030)
ln(Investment in physical capital) $_{t-1}$	0.012***	0.009**	0.007	0.008***	0.009***	0.001
	(0.003)	(0.004)	(0.009)	(0.002)	(0.002)	(0.002)
ln(ETC) $_{t-1}$	-0.001	0.001	-0.002	-0.001	-0.001	0.001
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
ln(R&D) $_{t-2}$	0.009***	0.002	0.017***	0.004	0.002	0.001
	(0.003)	(0.004)	(0.006)	(0.001)	(0.002)	(0.002)
Constant	0.519***	2.466***	0.695***	0.322***	2.564***	0.317***
	(0.127)	(0.258)	(0.174)	(0.049)	(0.332)	(0.109)
Wald test time-dummies (p-value)	5.73*** (0.000)	6.13*** (0.000)	3.17** (0.027)	17.30*** (0.000)	12.83*** (0.000)	4.92*** (0.000)
Wald test sectoral-dummies (p-value)	5.34*** (0.001)	-	3.17** (0.027)	3.48*** (0.000)	-	73.71*** (0.000)
R^2 (POLS) / R^2 within (FE)	0.99	0.63		0.99	0.68	
AR(1) (p-value)			0.000***			0.001***
AR(2) (p-value)			0.050**			0.063*
AR(3) (p-value)			0.377			0.251
Hansen test (p-value)			0.495 $\chi^2(77)$ (97 instruments)			0.336 $\chi^2(77)$ (111 instruments)

Notes: - Robust standard errors in parentheses; - * significance at 10%, ** 5%, *** 1%.

Source:
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Table 6: Dependent variable: ln(Employment);
Large (1,233 observations) and Small firms (1,171 observations)

	LARGE FIRMS			SMALLFIRMS		
	(1) POLS	(2) FE	(3) GMM-SYS	(1) POLS	(2) FE	(3) GMM-SYS
ln(Employment) $_{t-1}$	0.919***	0.850***	0.893***	0.898***	0.590***	0.871***
	(0.011)	(0.015)	(0.053)	(0.011)	(0.048)	(0.045)
ln(Value added)	0.058***	0.066***	0.068**	0.075***	0.075***	0.080***
	(0.009)	(0.011)	(0.028)	(0.012)	(0.016)	(0.025)
ln(Cost of labor per employee)	-0.139***	-0.166***	-0.202***	-0.224***	-0.426***	-0.266***
	(0.017)	(0.022)	(0.032)	(0.032)	(0.065)	(0.039)
ln(Investment in physical capital) $_{t-1}$	0.007***	0.007***	0.014	0.010***	0.010***	0.023***
	(0.002)	(0.002)	(0.009)	(0.002)	(0.003)	(0.007)
ln(ETC) $_{t-1}$	-0.0001	-0.0003	-0.002	-0.002	0.001	-0.006**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
ln(R&D) $_{t-2}$	0.001	0.003	0.001	0.001	0.002	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.262***	2.466***	0.479***	0.513***	2.484***	0.558***
	(0.059)	(0.258)	(0.115)	(0.077)	(0.188)	(0.113)
Wald test time-dummies	16.04***	117.73***	14.37***	7.23***	4.82***	2.82***
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)
Wald test sectoral-dummies	3.53***	-	3.14**	3.32***	-	2.48***
(p-value)	(0.000)		(0.000)	(0.000)		(0.000)
R^2 (POLS) / R^2 within (FE)	0.98	0.58		0.99	0.61	
AR(1) (p-value)			0.000***			0.000***
AR(2) (p-value)			0.019**			0.888
AR(3) (p-value)			0.156			-
Hansen test (p-value)			0.687 $\chi^2(77)$ (110 instruments)			0.190 $\chi^2(77)$ (129 instruments)

Notes: - Robust standard errors in parentheses; - * significance at 10%, ** 5%, *** 1%.

Source:
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Thank you for your kind attention

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