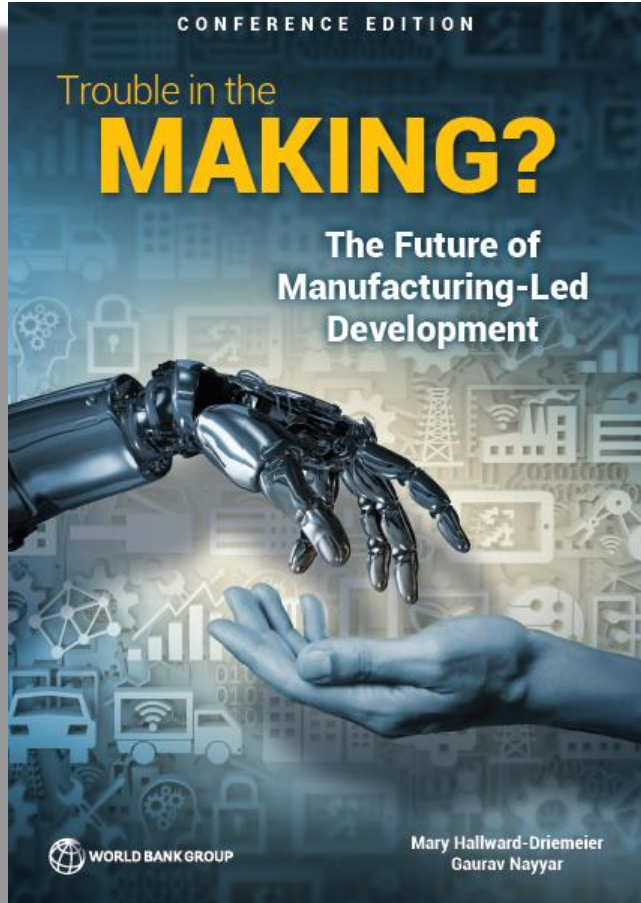# Automation and Offshoring in ECA's Manufacturing Sector:
Have Robots Grounded the Flying Geese?

Mary Hallward-Driemeier and Gaurav Nayyar

February 20, 2020

CONFERENCE EDITION

Trouble in the
MAKING?

**The Future of
Manufacturing-Led
Development**

Mary Hallward-Driemeier
Gaurav Nayyar

WORLD BANK GROUP

POLICY RESEARCH WORKING PAPER   9097
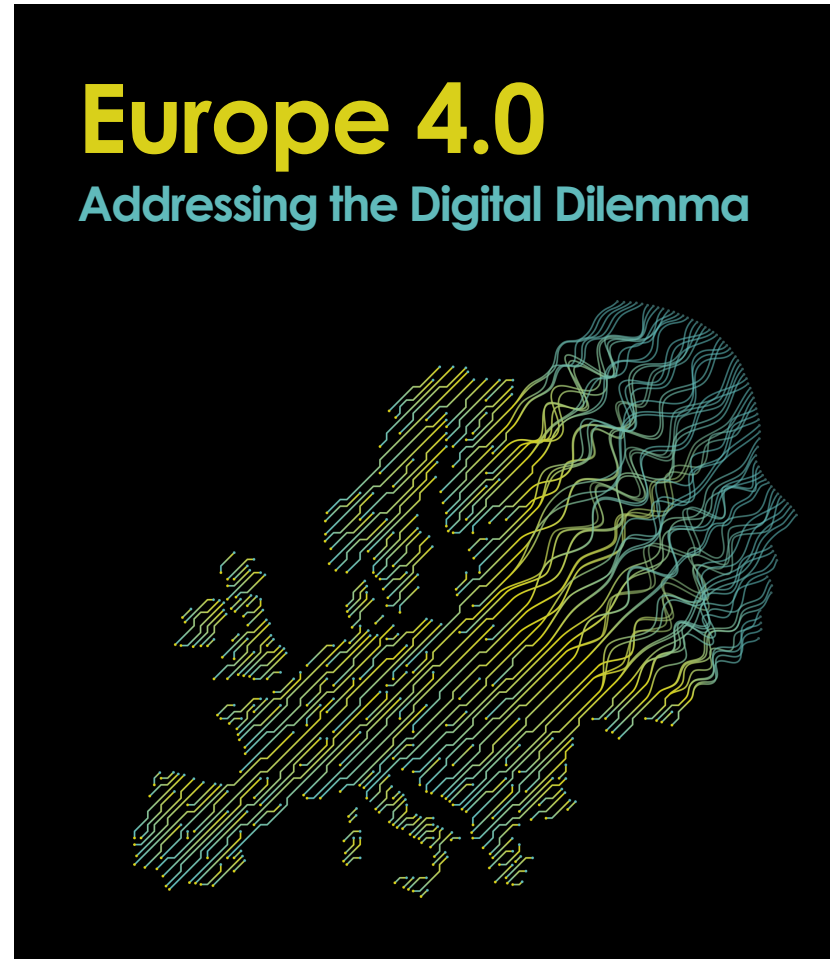
Have Robots Grounded the Flying Geese?

Evidence from Greenfield FDI in Manufacturing

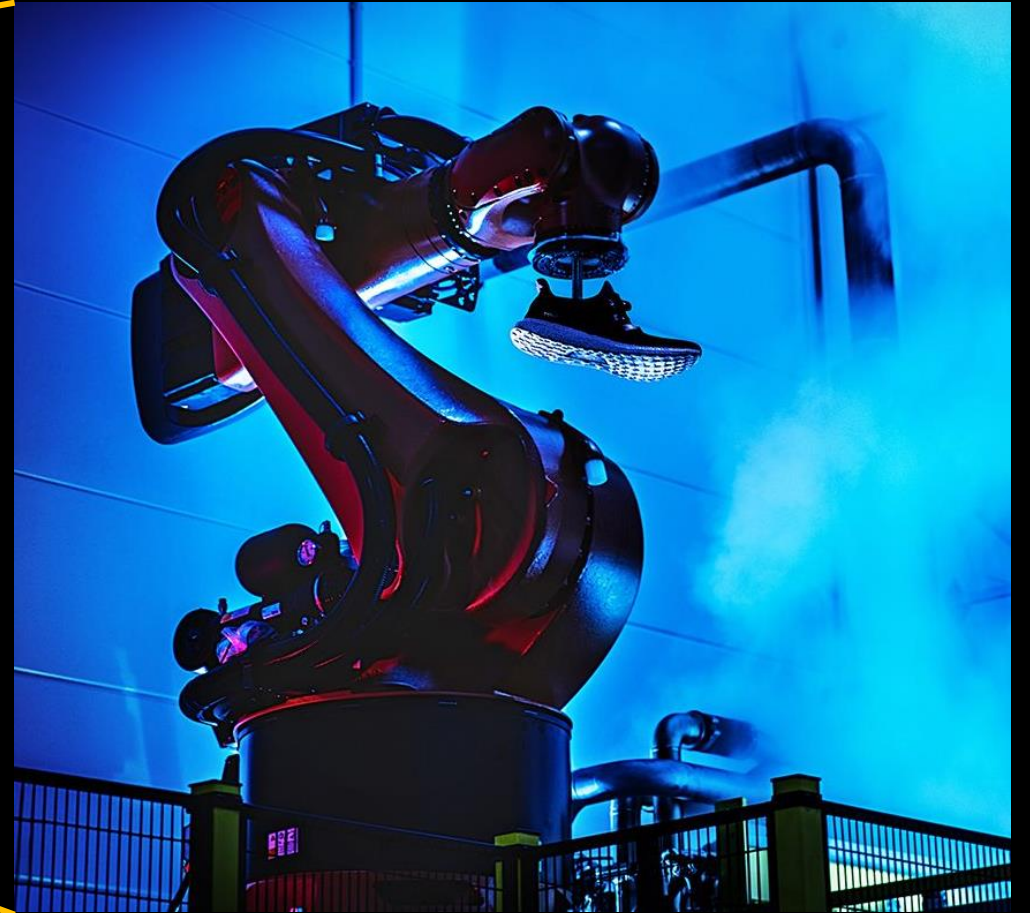*Mary Hallward-Driemeier*
Gaurav Nayyar

WORLD BANK GROUP
Finance, Competitiveness and Innovation Global Practice
December 2019

Europe 4.0
Addressing the Digital Dilemma

Grounded?

All hype?

Technologically feasible
Economically viable

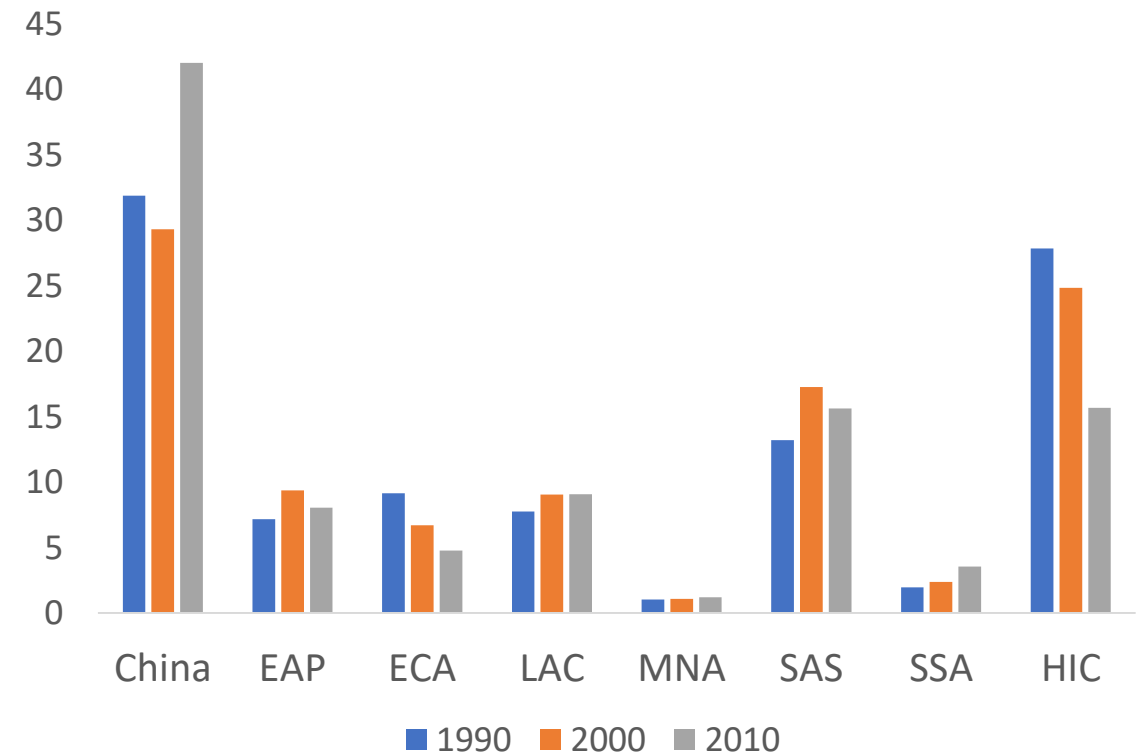# Literature on impact of HIC's automation on developing countries

- Artuc, Bastos and Rijkers (2019) show that a 10-percentage point increase in robot density in developed countries is associated with a 6.1 percentage point increase in their imports from less developed countries and a 11.8 percentage point increase in their exports to these countries

- Comparing growth in hearing aid trade – which is entirely 3D printed – with other similar products, Freund, Mulabdic and Ruta (2019) find that 3D printing increased trade by 58 percent over a decade. Early innovators in Europe, such as Denmark and Switzerland, remain the main export platforms.
  - Beyond hearing aids, the authors find that 35 products that are increasingly being 3D printed have also experienced faster trade growth relative to other similar goods.

- Kinkel, Jager and Zanker (2015) using data on 3000 firms, find that firms using industrials robots in their manufacturing processes are less likely to offshore production activities outside Europe.

- Artuc, Christiaensen, and Winkler (2019) show that an increase of one robot per thousand workers in the U.S.—about twice the increase observed between 2004–2014—lowers growth in exports per worker from Mexico to the U.S. by 6.7 percent.

Changing distribution across countries

Manufacturing value added
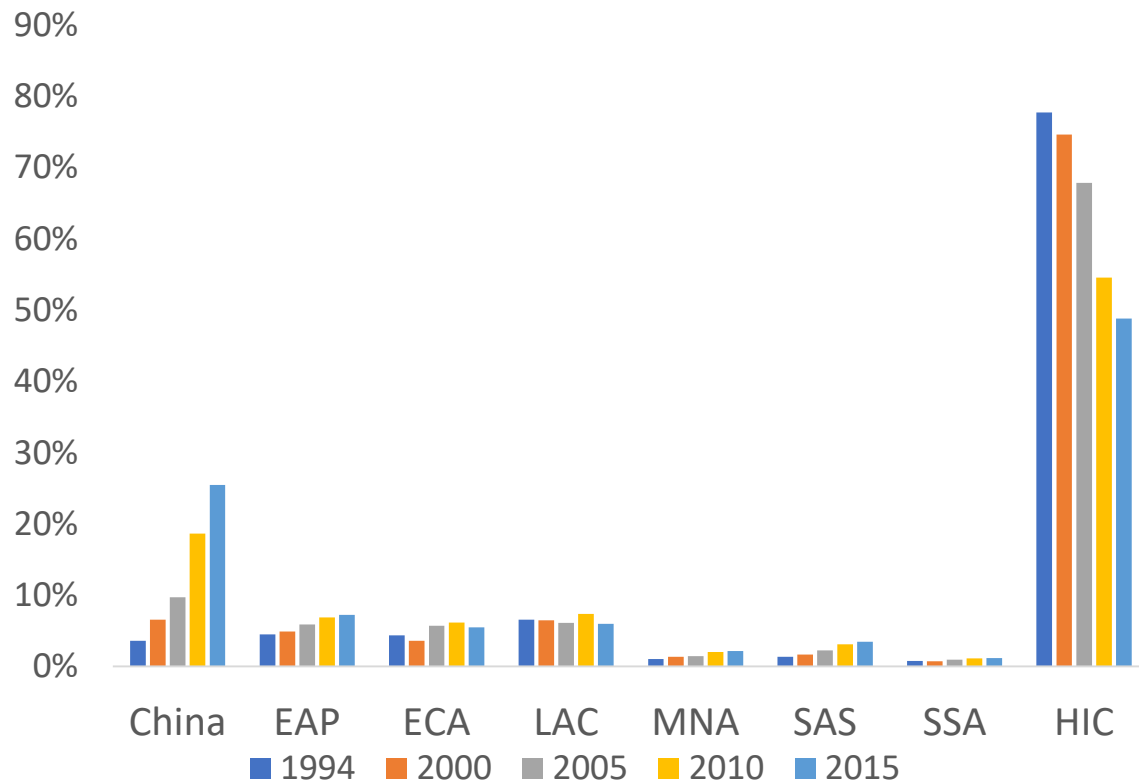
Manufacturing employment

WORLD BANK GROUP
Trade & Competitiveness

Changing distribution within countries

3 out of 4 countries are 'deindustrializing' – but almost all in relative rather than absolute terms.

Services are growing faster.

Ratio of change in absolute term of MVA (constant 2010 USD)

Change in the Share of Manufacturing Value Added (% points)

● HIC ● UMC ● LMIC ● LIC

WORLD BANK GROUP
Trade & Competitiveness
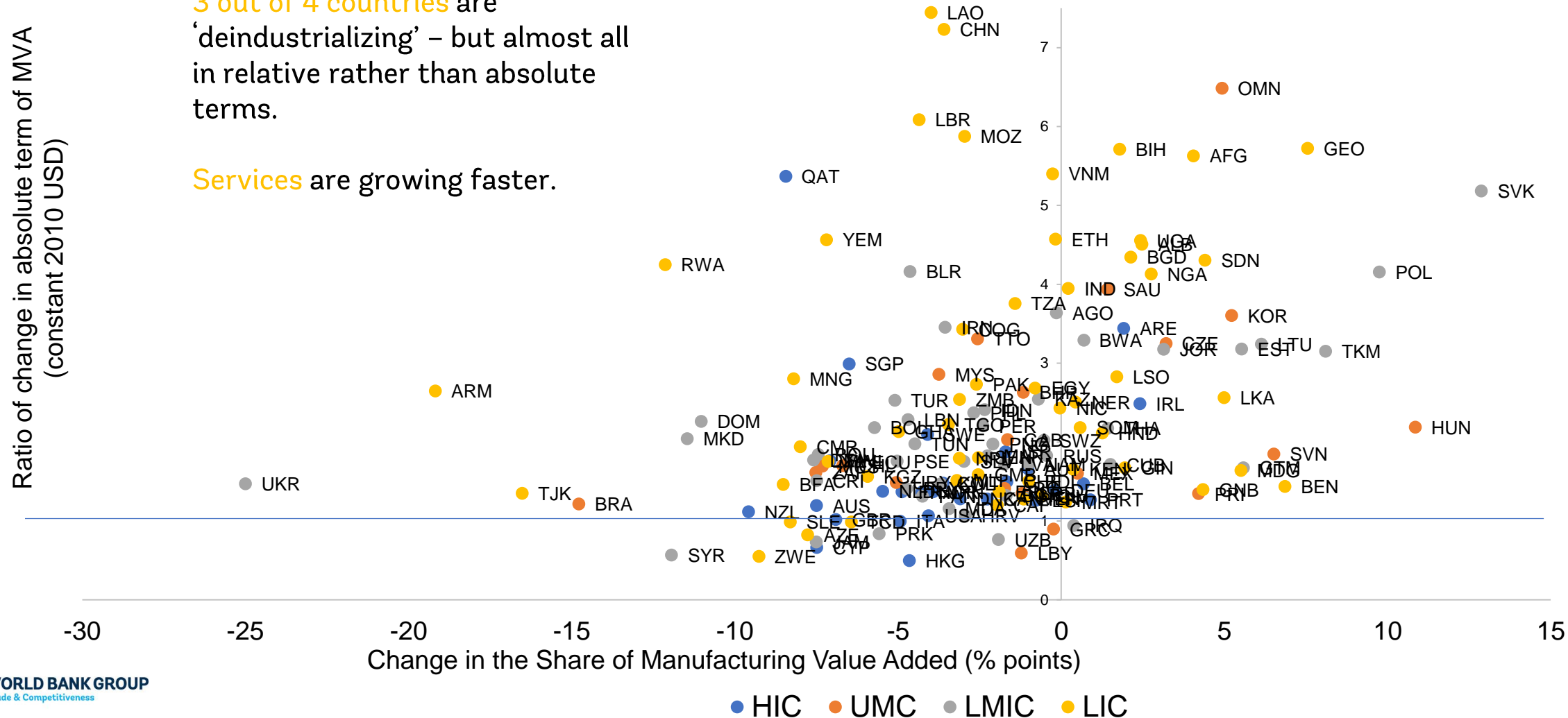
Changing composition of sectors over time

High-income

Declines in manufacturing value added as a share of GDP confirm that large HICs are deindustrializing across most sector groupings
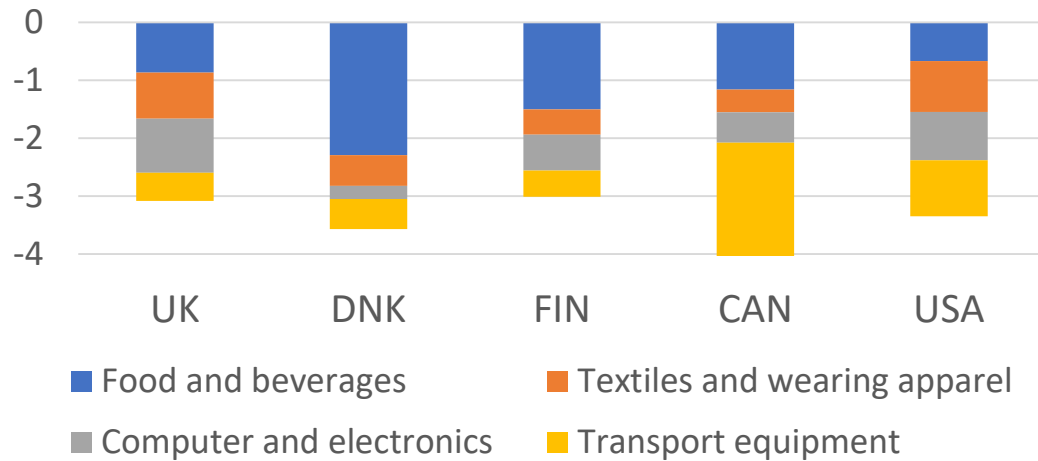
Upper **middle-income**

Several of the industrializing upper-middle-income countries exhibit shifts in sector composition as per the "flying geese"
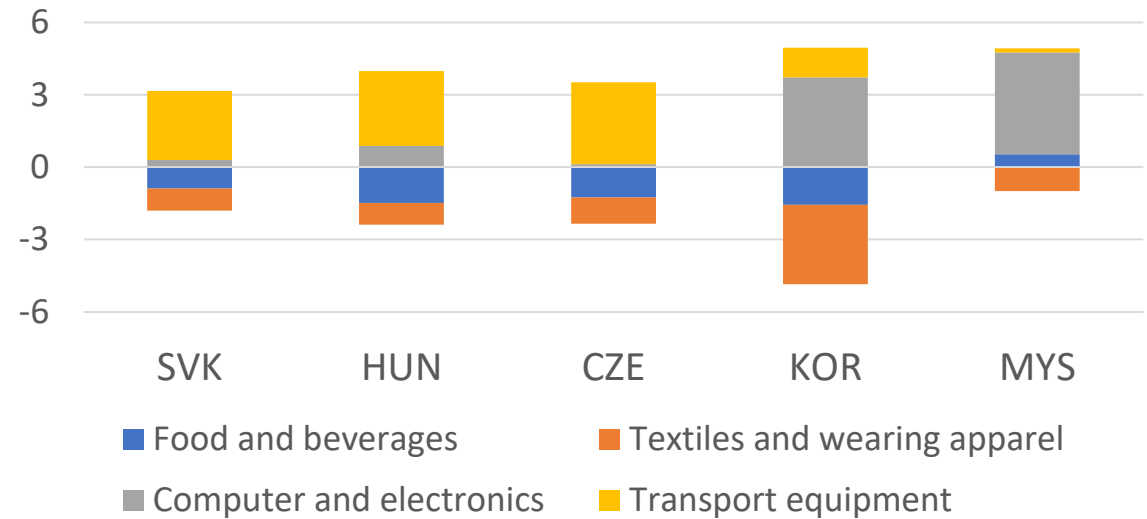
Source: United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database.

Lower income countries either are concentrated in labor intensive tradables or regional commodity processing – if at all

ECA's comparative advantage is in medium-skilled global innovators (transportation, electronics, electrical machinery); somewhat in garments and textiles

b. Low-skill labor-intensive tradables
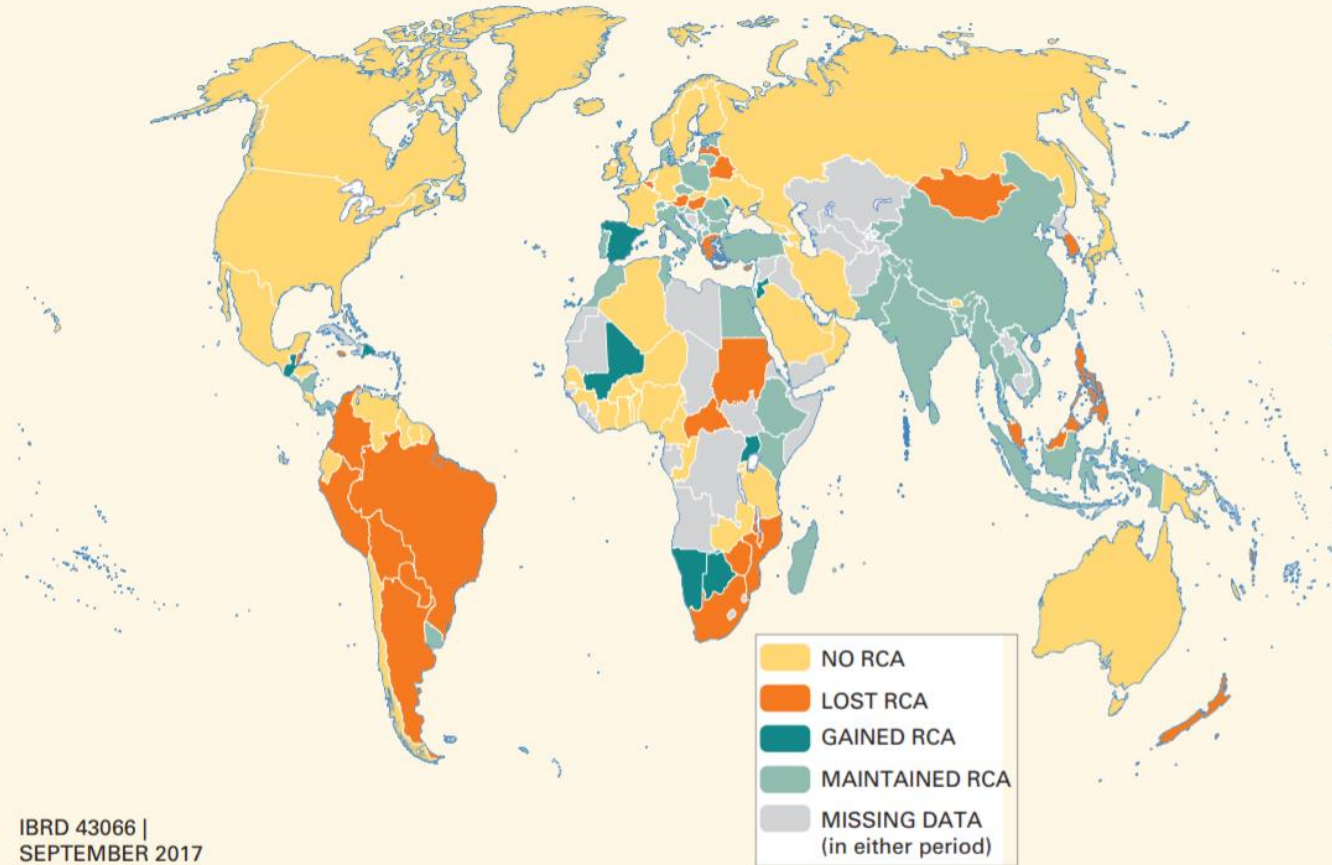
d. Medium-skill global innovators

NO RCA
LOST RCA
GAINED RCA
MAINTAINED RCA
MISSING DATA (in either period)

IBRD 43066 | SEPTEMBER 2017

IBRD 43067 | SEPTEMBER 2017

WORLD BANK GROUP
Trade & Competitiveness

Source: World Development Indicators database.
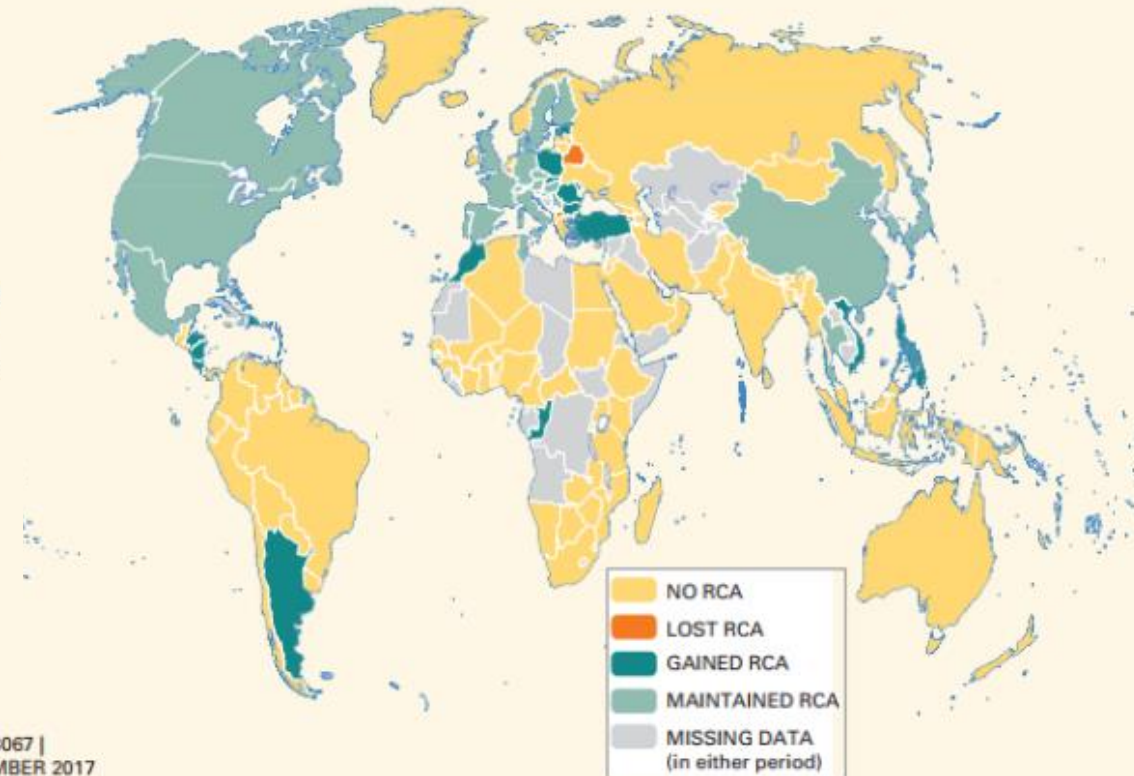
Cumulative FDI projects from HICs to LMICs
by source country, 2004-2015 (log scale)
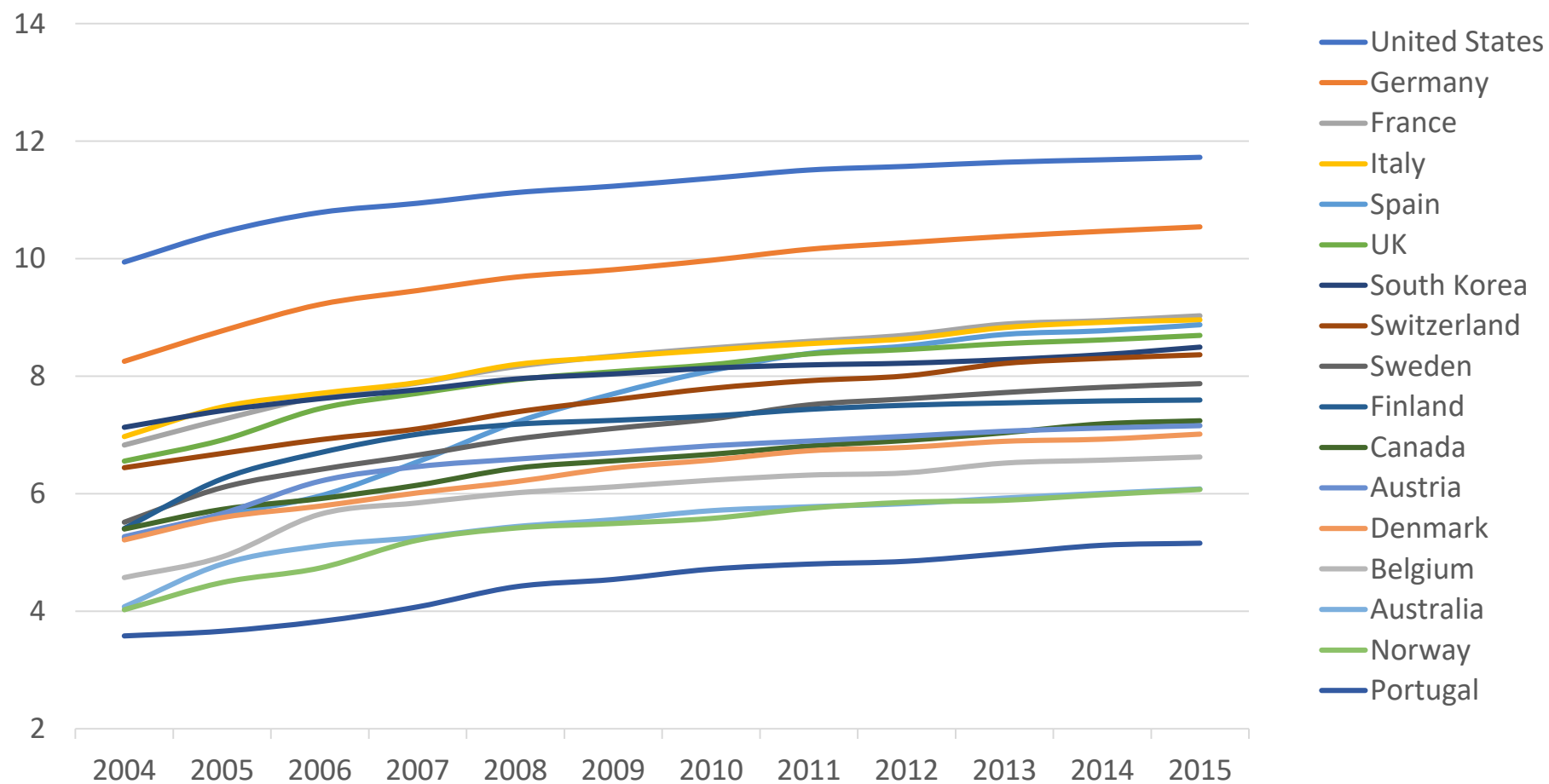
Source: Calculations based on fDi Markets Database

Cumulative Number of FDI projects from HICs to LMICs, by sector, 2004-2015 (log scale)
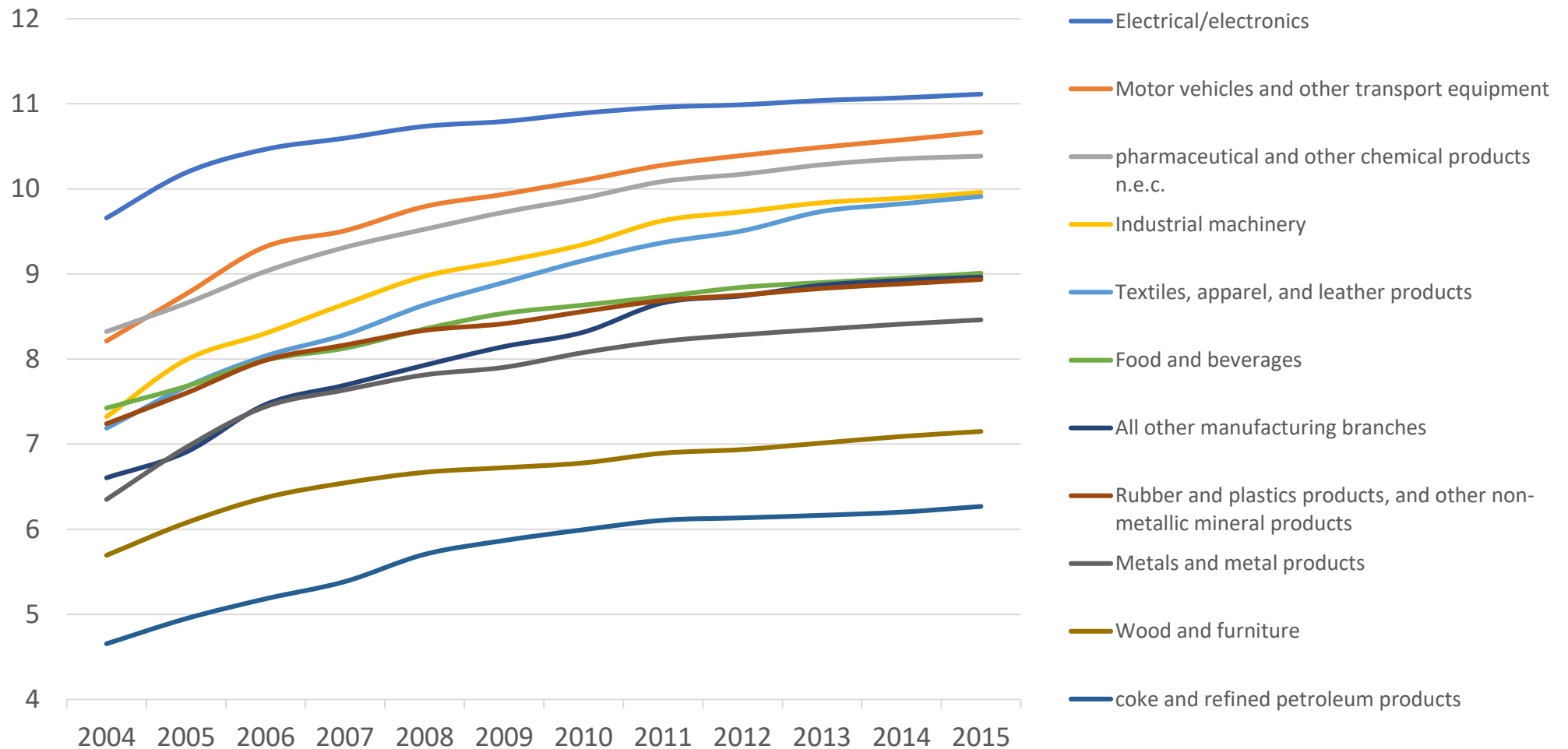
Operational Stock of Robots per 1000 Employees

Legend: South Korea, Germany, Sweden, United States, Denmark, Belgium, Spain, Italy, Finland, France, Austria, UK, Switzerland, Portugal, Norway, Australia
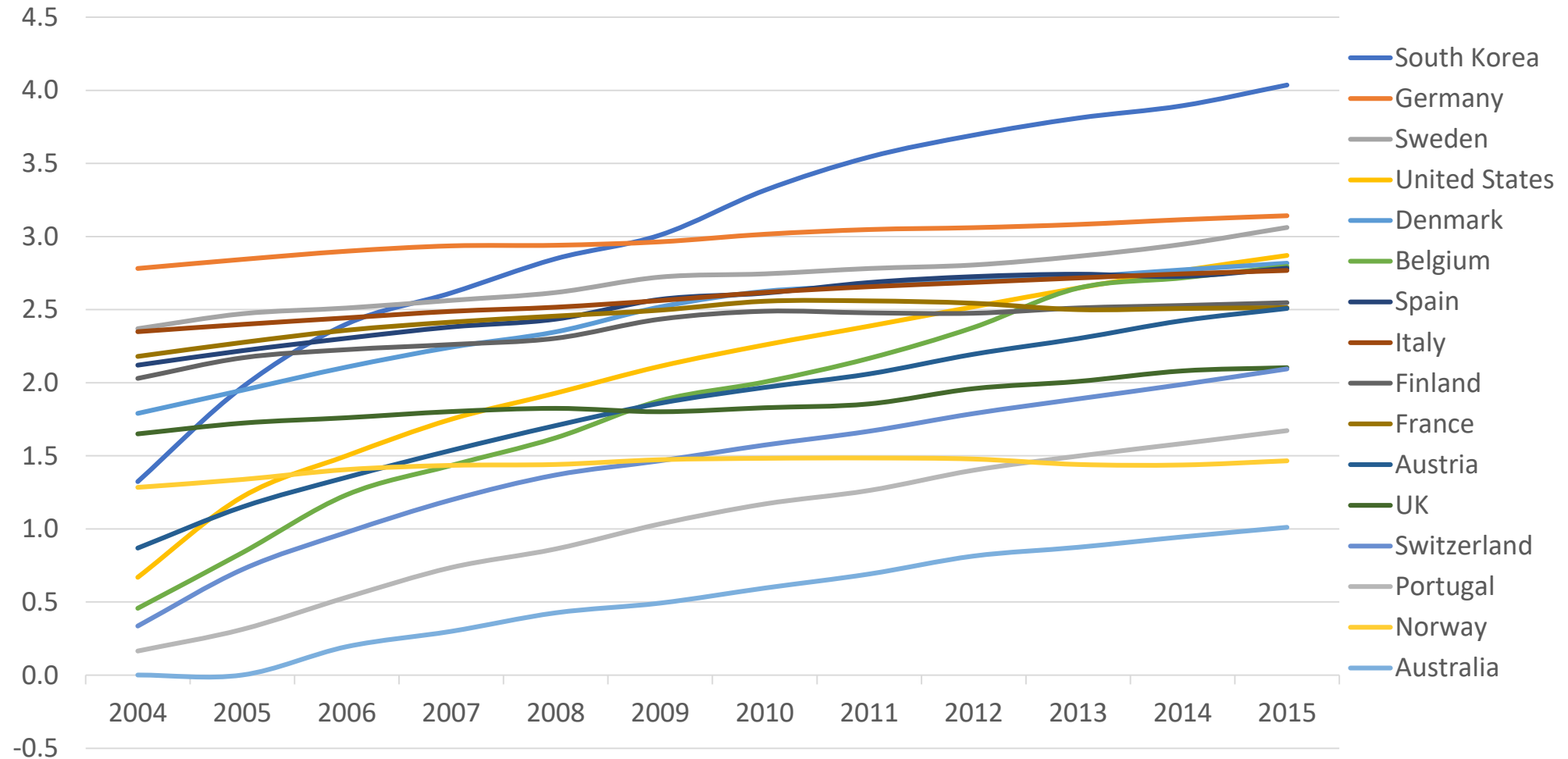
Operational Stock of Robots per 1000 Employees in HICs, by sector, 2004-2015

Legend:
- Motor vehicles and other transport equipment
- Electrical/electronics
- Rubber and plastics products, and other non-metallic mineral products
- Metals and metal products
- Industrial machinery
- Food and beverages
- All other manufacturing branches
- Wood and furniture
- Textiles, apparel, and leather products
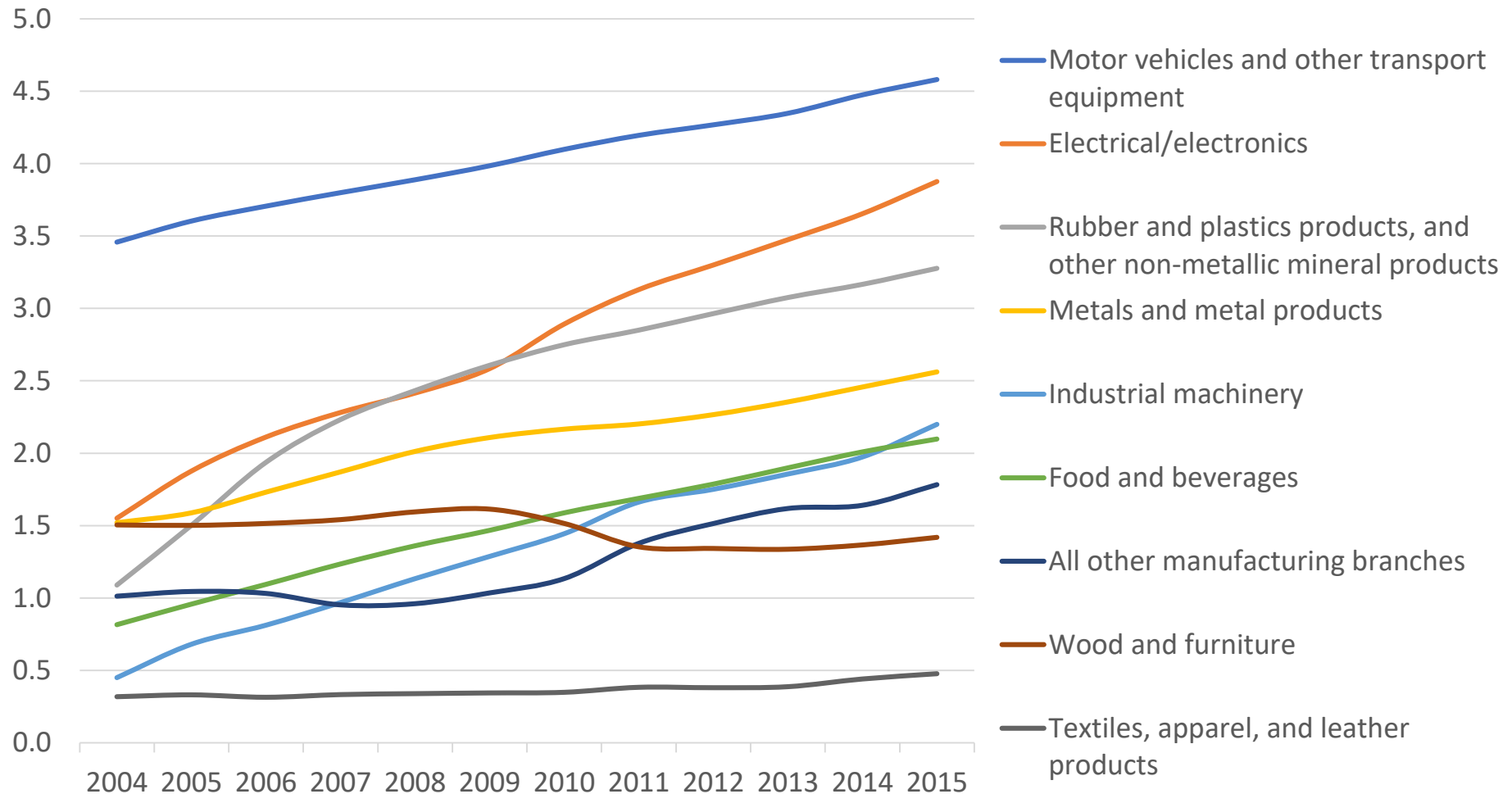
Ratio of Robot Stock per 1000 Employees in electronics to apparel in HICs and Ratio of Cumulative FDI Flows in electronics to apparel from HICs to LMICs, 2003-2015

— Robots per 1000 employees in electronics relative to apparel

— Cumulative FDI flows from HIC to LMICs in electronics relative to apparel
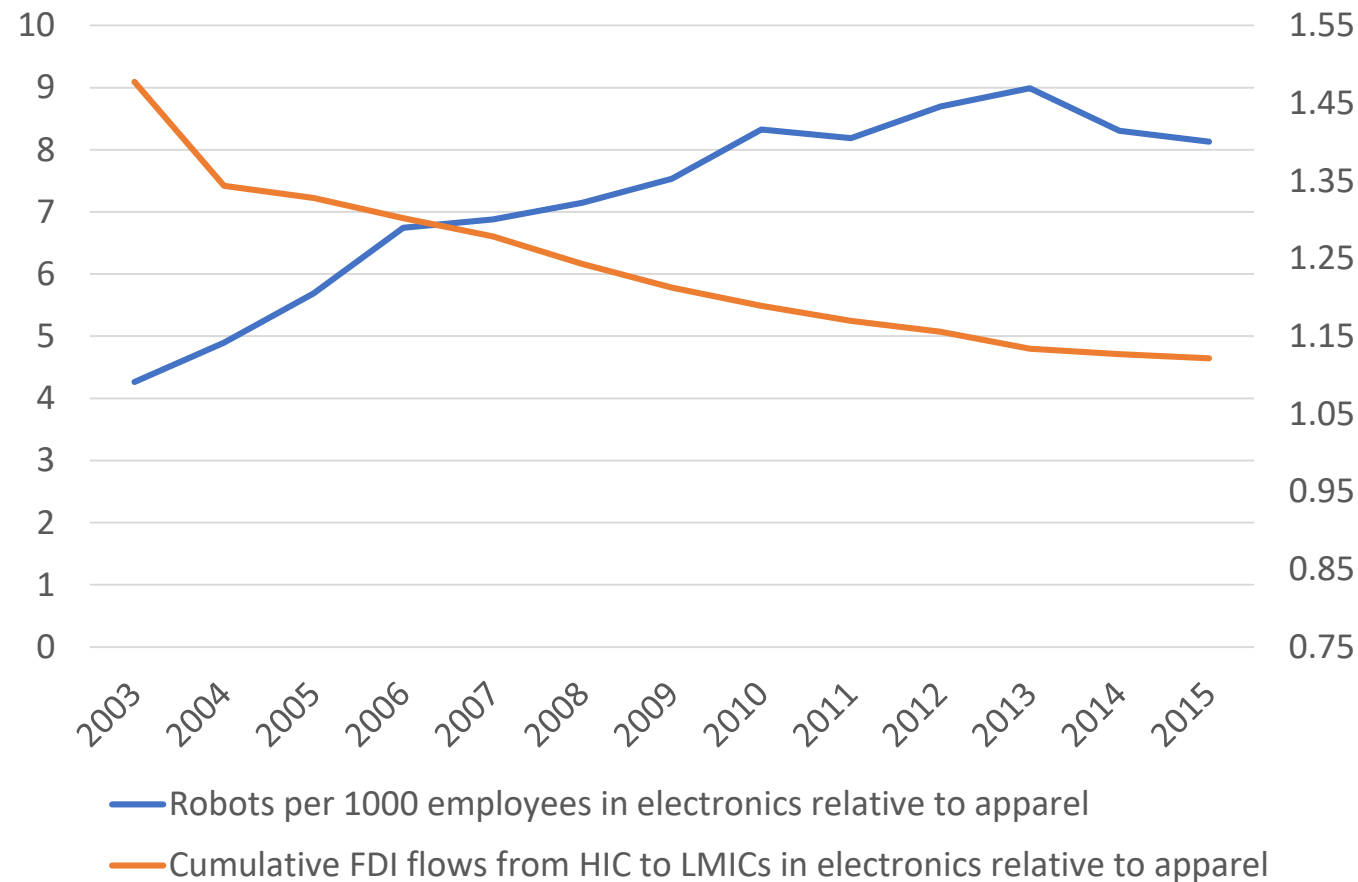
Estimation

$$\ln(1 + FDI)_{ist} = \alpha + \beta_1 \ln(1 + Robots_{ist}) + \beta_2 [\ln(1 + Robots_{ist})]^2 + \ln(1 + Exports_{ist}) + \gamma_{is} + \delta_{it} + \varepsilon_{ist}$$

- Estimate impact of automation on outbound FDI at the country-sector-year level
- Controlling for country-sector and country-year fixed effects
- Allow for non-linear impacts of automation
- And control for exports, other ICT intensity

OLS

1. Direct effect is positive and significant

	Full sample
	(1)
Ln (1 + Exports)	-0.0123 (0.0415)
Ln (1 + Robots per 1000 employees)	0.0551** (0.0224)
Ln (1 + Robots per 1000 employees-squared)	
Country-sector fixed effect	Yes
Country-year fixed effect	Yes
R-squared	0.980
Observations	2,208

OLS

1. Direct effect is positive and significant
2. The non-linear effect is negative

	Full sample	Full sample
	(1)	(2)
Ln (1 + Exports)	-0.0123 (0.0415)	-0.0160 (0.0415)
Ln (1 + Robots per 1000 employees)	0.0551** (0.0224)	0.1329*** (0.0426)
Ln (1 + Robots per 1000 employees-squared)		-0.0209** (0.0098)
Country-sector fixed effect	Yes	Yes
Country-year fixed effect	Yes	Yes
R-squared	0.980	0.980
Observations	2,208	2,208

OLS

1. Direct effect is positive and significant
2. The non-linear effect is negative
3. But – only for middle income countries

	Full sample	Full sample	To low-income countries only	To middle-income countries only
	(1)	(2)	(3)	(4)
Ln (1 + Exports)	-0.0123 (0.0415)	-0.0160 (0.0415)	0.0525 (0.1026)	0.0184 (0.0465)
Ln (1 + Robots per 1000 employees)	0.0551** (0.0224)	0.1329*** (0.0426)	0.1624* (0.0985)	0.1722*** (0.0476)
Ln (1 + Robots per 1000 employees-squared)		-0.0209** (0.0098)	.0126673 (.0235536)	-0.0187* (0.0109)
Country-sector fixed effect	Yes	Yes	Yes	Yes
Country-year fixed effect	Yes	Yes	Yes	Yes
R-squared	0.980	0.980	0.801	0.977
Observations	2,208	2,208	840	2,196

Robustness – not driven by one sector or by China; larger effects in more recent period

	Pre-crisis period	Post-crisis period	Transport equipment sector excluded	China included as a source country, but excluded as a destination	IT stock included as an explanatory variable
	(1)	(2)	(3)	(4)	(5)
Ln (1 + Exports)	-0.2291* (0.1213)	0.033 (0.0359)	0.0139 (0.0623)	.0281136 (.0419495)	0.0079 (0.0578)
Ln (1+ Robots per 1000 employees)	-0.1202 (0.1158)	0.132*** (0.045)	0.3907*** (0.0845)	0.1832*** (0.0428)	0.2331*** (0.0688)
Ln (1 + Robots per 1000 employees-squared)	0.0553 (0.0349)	-0.0179** (0.0103)	-0.1048*** (0.0220)	-0.0293*** (0.0101)	-0.0639*** (0.0162)
Ln (1+ IT stock per 1000 employees)					-0.1086* (0.0588)
Country-sector fixed effect	Yes	Yes	Yes	Yes	Yes
Country-year fixed effect	Yes	Yes	Yes	Yes	Yes
R-squared	0.986	0.995	0.981	0.979	0.983
Observations	736	1,288	1,157	2,340	1,275

Instrumental variable estimation – results are stronger (i.e. controls for feedback from FDI to lower incentive to automate)

	Full sample
	(1)
Exports	-0.00367
	(0.0586)
Robots per 1000 employees	0.2276**
	(0.1239)
Robots per 1000 employees-squared	-0.0793***
	(0.0286)
IT stock per 1000 employees	-0.0832
	(0.0613)
Country-sector fixed effect	Yes
Country-year fixed effect	Yes
Observations	1275
(Centered) R-squared	0.983
Under identification test (Anderson canon. corr. LM statistic)	366.909
Weak identification test (Cragg-Donald Wald F statistic)	213.133
Instrumented	robots per 1000 employees, robots per 1000 employees-squared;
Instruments	robots per 1000 employees in the 4 most similar countries in terms of GDP per capita, and squared

Instrumental variable estimation – results are stronger (i.e. controls for feedback from FDI to lower incentive to automate)
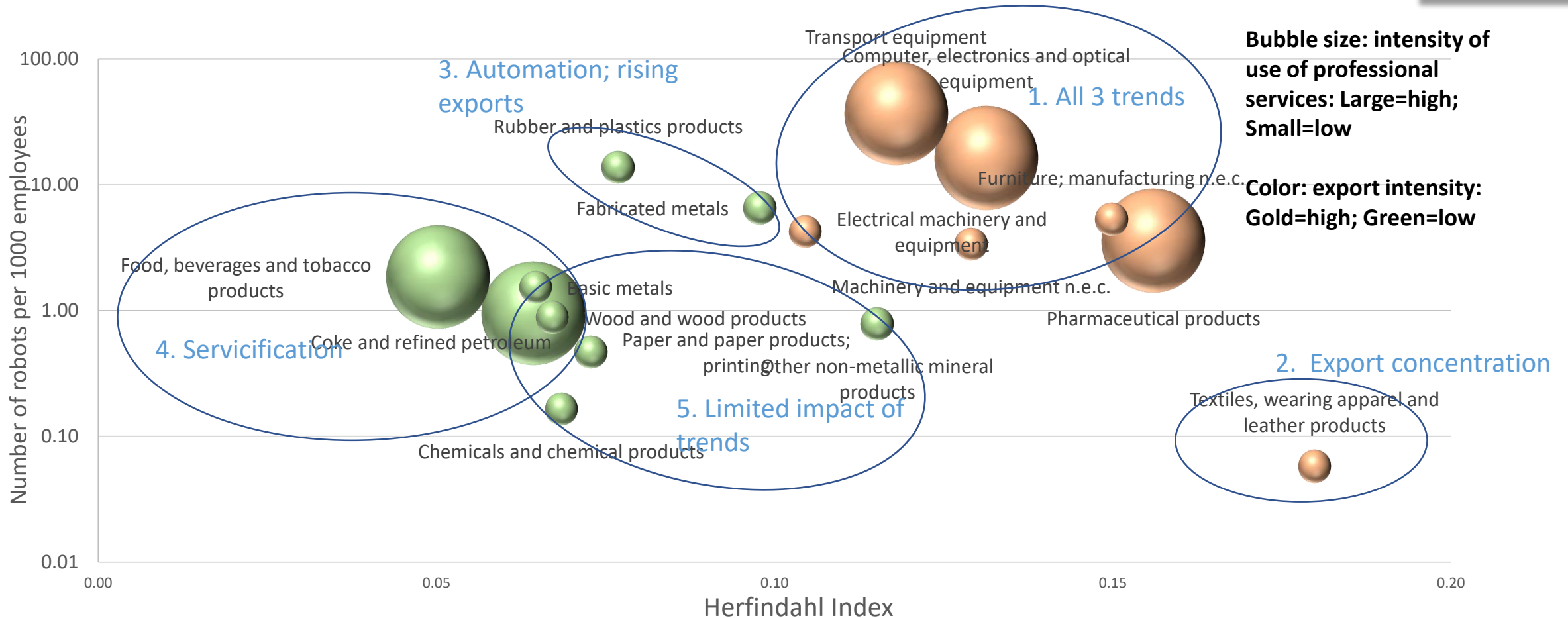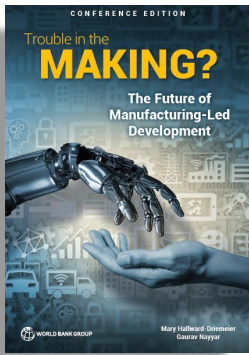
	Full sample	Transportation equipment sector excluded	China included as a source country, but excluded as a destination country
	(1)	(2)	(3)
Exports	-0.00367	0.0085	-0.0044
	(0.0586)	(0.0637)	(0.0586)
Robots per 1000 employees	0.2276**	0.6546***	0.2269*
	(0.1239)	(0.2284)	(0.1243)
Robots per 1000 employees-squared	-0.0793***	-0.2123***	-0.0778***
	(0.0286)	(0.0665)	(0.0286)
IT stock per 1000 employees	-0.0832	-0.0518	-0.0023
	(0.0613)	(0.0707)	(0.0021)
Country-sector fixed effect	Yes	Yes	Yes
Country-year fixed effect	Yes	Yes	Yes
Observations	1275	1157	1275
(Centered) R-squared	0.983	0.981	0.983
Under identification test (Anderson canon. corr. LM statistic)	366.909	127.493	366.162
Weak identification test (Cragg-Donald Wald F statistic)	213.133	58.638	212.525
Instrumented	robots per 1000 employees, robots per 1000 employees-squared;		
Instruments	robots per 1000 employees in the 4 most similar countries in terms of GDP per capita, and squared		

Nearshoring? Not in ECA

Dependent variable: Natural logarithm of share of FDI among a "region pair"

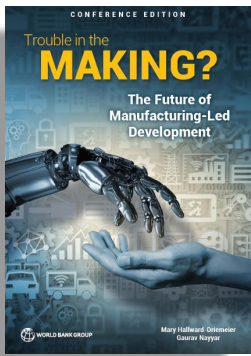|	Full sample	Europe and Central Asia only
	(1)	(2)
Ln (1 + Exports)	0.0082 (0.0119)	0.0189 (0.0123)
Ln (1 + Robots per 1000 employees)	-0.0181 (0.0119)	-0.0444*** (0.0139)
Ln (1 + Robots per 1000 employees-squared)	-0.0042 (0.0028)	0.0005 (0.0033)
Country-sector fixed effect	Yes	Yes
Country-year fixed effect	Yes	Yes
R-squared	0.866	0.883
Observations	2,021	1,741

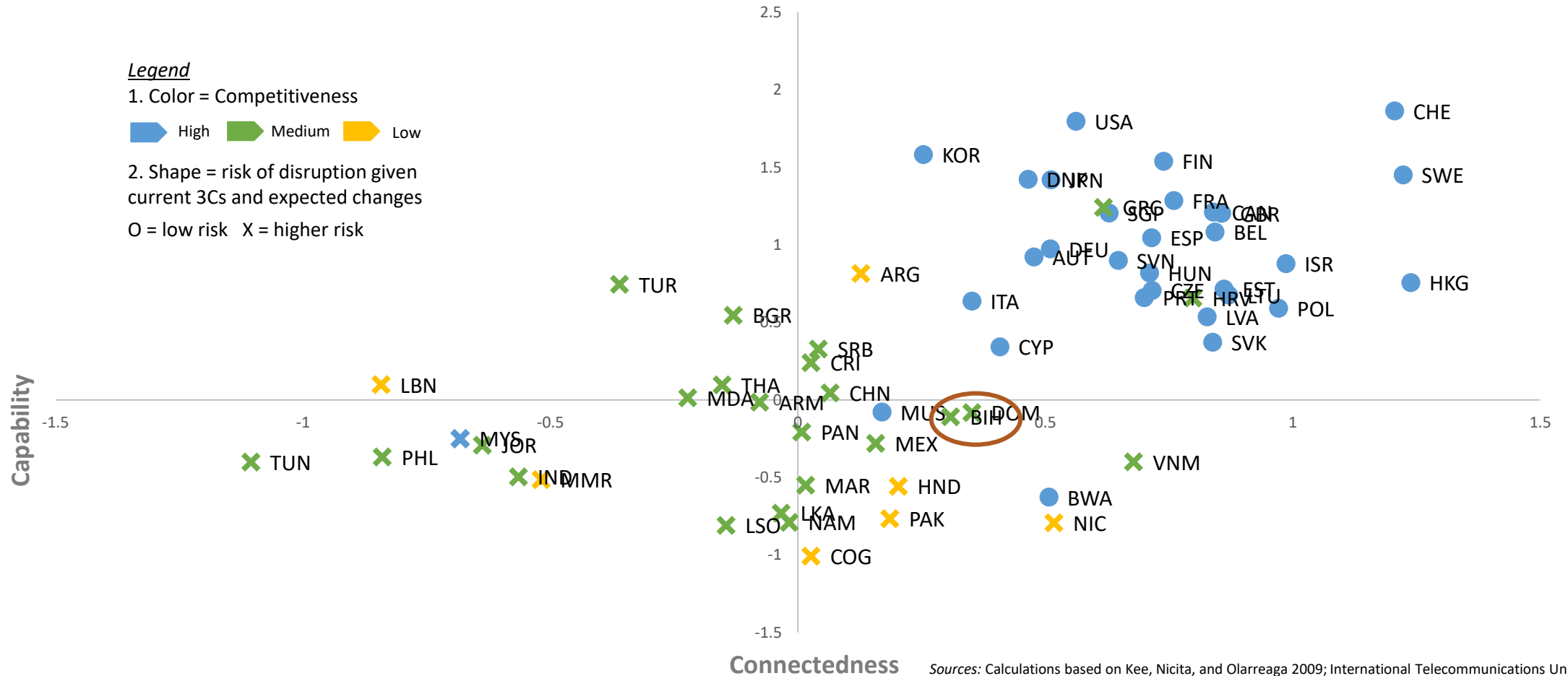# The extent the bar is rising varies by the relative magnitude of these trends, conditional on a sector's tradedness

Bubble size: intensity of use of professional services: Large=high; Small=low

Color: export intensity: Gold=high; Green=low

3. Automation; rising exports

1. All 3 trends

4. Servicification

5. Limited impact of trends

2. Export concentration

Transport equipment

Computer, electronics and optical equipment

Rubber and plastics products

Furniture; manufacturing n.e.c.

Fabricated metals

Electrical machinery and equipment

Food, beverages and tobacco products

Basic metals

Machinery and equipment n.e.c.

Wood and wood products

Coke and refined petroleum

Paper and paper products; printing

Other non-metallic mineral products

Pharmaceutical products

Chemicals and chemical products

Textiles, wearing apparel and leather products

Number of robots per 1000 employees

100.00

10.00

1.00

0.10

0.01

0.00   0.05   0.10   0.15   0.20

Herfindahl Index

3Cs: Competitiveness, Capabilities, and Connectedness

High Competitiveness

Medium Competitiveness

Low Competitiveness

Capabilities (vertical axis): 2.0, 1.5, 1.0, -1.0, -1.5

Connectedness (horizontal axis): -2.3, -1.8, -1.3, -0.8, -0.3, 0.3, 0.8, 1.3, 1.8

Countries: CHE, USA, KOR, FIN, NZL, SWE, DNK, NLD, GRC, FRA, SGP, CAN, GBR, BEL, NOR, DEU, ESP, RUS, AUT, SVN, ISR, BLR, HUN, HKG, ARG, CZE, EST, PRT, HRV, LTU, RUS, TUR, LVA, URY, POL, VEN, BGR, TTO, SVK, UKR, SAU, ITA, CYP, BHR, CRI, MKD, MNG, KAZ, ARE, BRA, THA, JOR, CHN, MDA, ARM, MUS, DOM, ECU, PAK, AZE, BLZ, PER, MYS, MEX, KGZ, ZAF, PRY, VNM, EGY, TUN, PHL, JAM, DZA, SLV, IDN, GTM, MAR, BOL, OMN, QAT, IND, KWT, BWA, MLI, IRQ, AGO, YEM, CMR, LKA, PAK, BGD, RWA, NIC, AFG, SEN, ZMB, ETH, NPL, GIN, NGA, PNG, NER, BFA, COG, GHA, UGA, MOZ, TZA, GMB, MWI, MRT

Sources: Calculations based on Kee, Nicita, and Olarreaga 2009; International Telecommunications Union's ICT Indicators Database; and the following World Bank databases: World Development Indicators, Worldwide Governance Indicators, Global Findex, Logistics Performance Index, and Services Trade Restrictiveness Index.
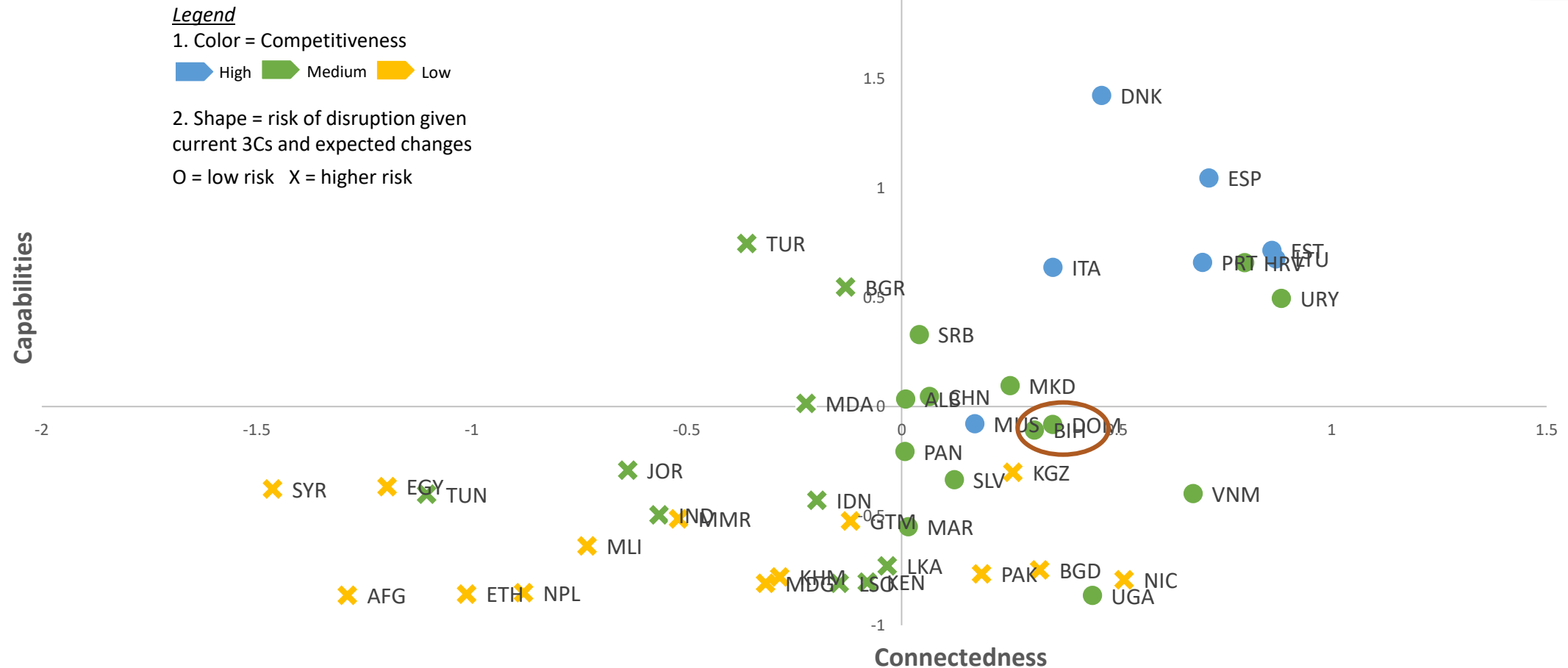
Scenario 1: All 3C's needed (transport equipment, electronics, pharmaceutical, electrical machinery, machinery and equipment n.e.c and manufacturing n.e.c)

Legend

1. Color = Competitiveness

High   Medium   Low

2. Shape = risk of disruption given current 3Cs and expected changes

O = low risk   X = higher risk

Capability

Connectedness

Sources: Calculations based on Kee, Nicita, and Olarreaga 2009; International Telecommunications Union's ICT Indicators Database; and the following World Bank databases: World Development Indicators, Worldwide Governance Indicators, Global Findex, Logistics Performance Index, and Services Trade Restrictiveness Index.

Scenario 2: Higher competitiveness and high connectedness needed (textiles, apparel, and leather products)

Legend
1. Color = Competitiveness

High   Medium   Low

2. Shape = risk of disruption given current 3Cs and expected changes

O = low risk   X = higher risk

Capabilities

Connectedness
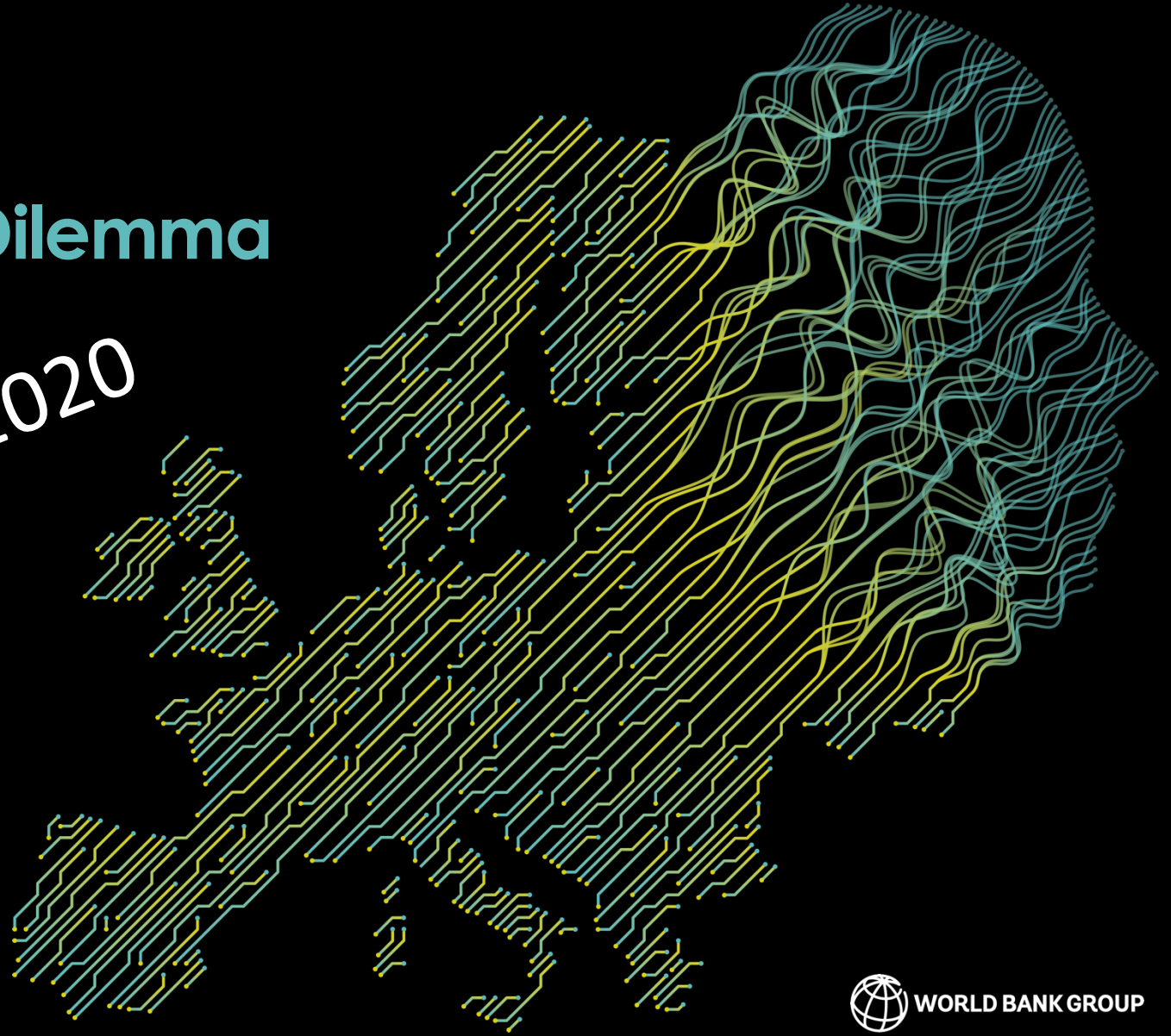
Digital technology is not monolithic…

	TRANSACTIONAL	INFORMATIONAL	OPERATIONAL
Technology category			
Source of efficiency gains	Matching supply and demand	Computing and storage	Replace labor
Types of technologies	Cloud computing Big data analytics Machine learning	Platforms Blockchain	Smart robots 3D printing Drones

Source: Europe 4.0 Team

…which matters for Europe to attain its Triple Objective

	Transactional	Informational	Operational
Europe's competitive position			
Impact on market inclusion			
Impact on geographic convergence			

Key messages

- Manufacturing will remain a part of development strategies, although likely with fewer dual benefits of productivity and jobs

- Some manufacturing industries will remain feasible entry points for less-industrialized countries and drivers of low-skill employment

- New sources of growth -- Services are both increasingly important for the success of manufacturing and themselves a source of dynamic gains and employment

- Urgency rather than alarmism is appropriate

- Need to balance current focus on disruptions with positioning for new opportunities

- Ensure inclusive access to technology – and that technology contributes to inclusive outcomes

Thank you