Technology Capabilities Development and Scientific Knowledge Production

STI models, R&D indicators, empirics and evaluation

Robert Tijssen

CWTS, Leiden University, Netherlands

CREST, Stellenbosch University, South Africa

International Symposium

“Challenges of Technology and Economic Catching-Up in Emerging Economies”

3-4 July 2019, University of Campinas (Brazil)

Outline of presentation

STI perspective (macro, meso and micro level)

Conceptual and analytical models

Comparative measurement of R&D capabilities, processes and outputs

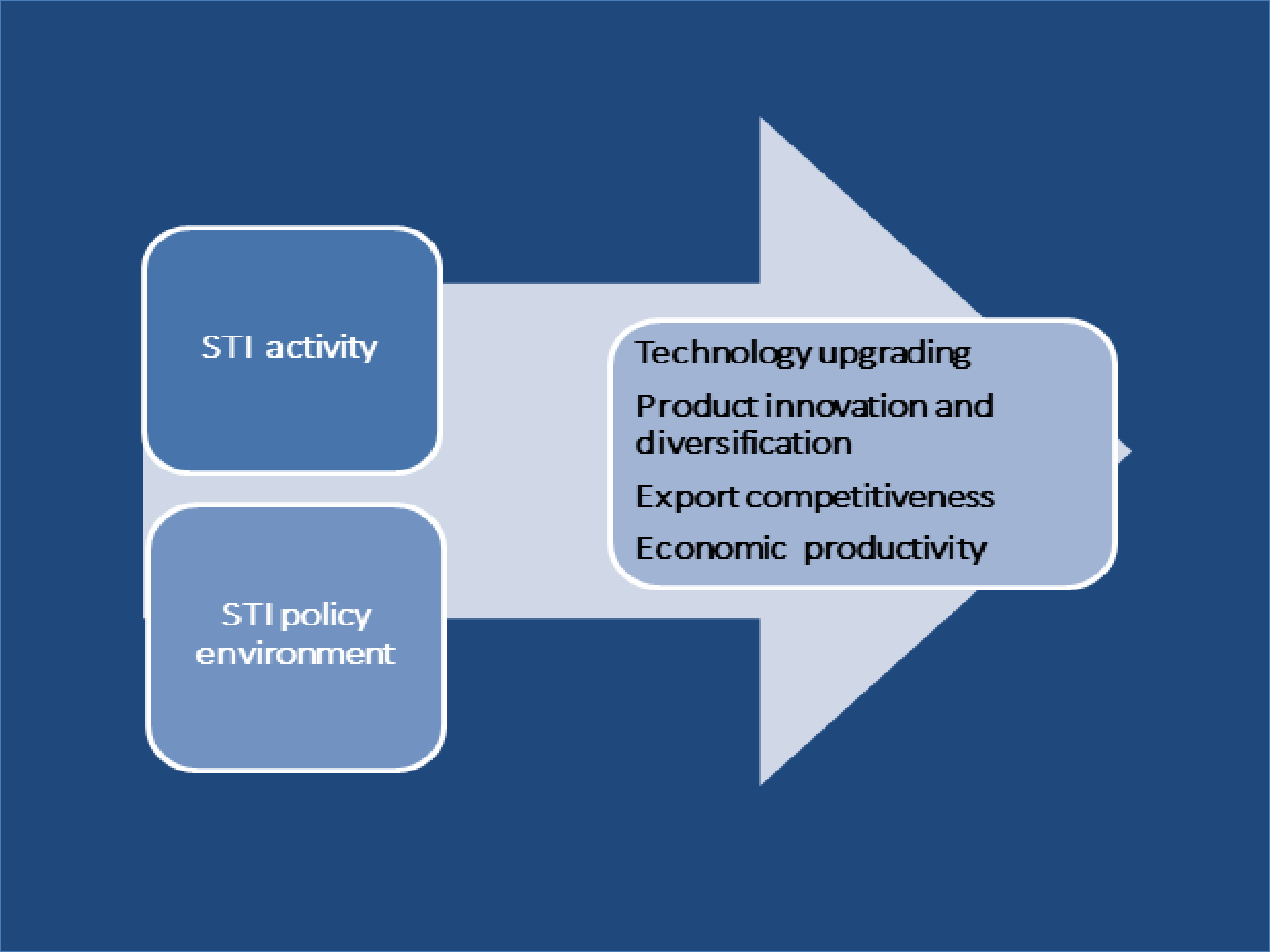
Public science contributions (research intensive universities)

R&D performance indicators (quantitative)

Indicator testing and application: case study examples

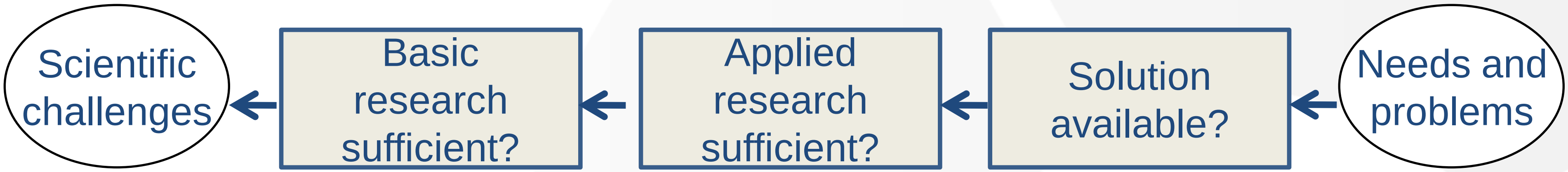
Lessons drawn and next analytical steps

How does
technology capabilities development
(and technology upgrading)
relate to public
scientific knowledge production
and dissemination ?

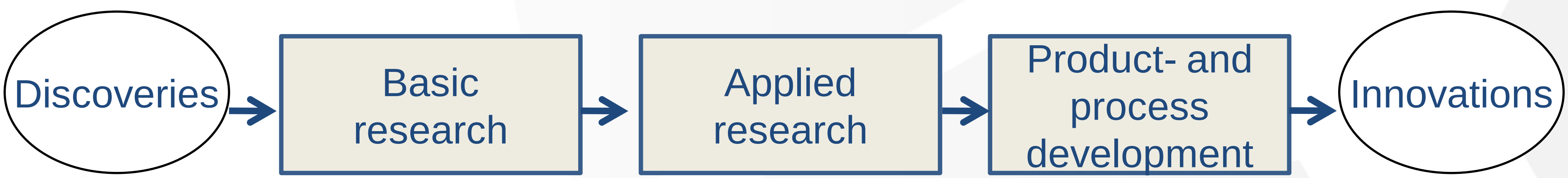

STI activity
STI policy environment
Technology upgrading
Product innovation and diversification
Export competitiveness
Economic productivity

‘STI activity’

Market-driven ‘demand pull’ model



Science-driven ‘technology push’ model



'STI policy environment' and analytical approaches

	Market failure	System failure	Emergence failure
Rationale for policy	Insufficient investment in R&D because its benefits are not fully captured by the firms carrying it out	Disconnections between researchers and industry due to differences in culture, goals and values	Uncertainty and complexity hinder the application of new technologies to tackle societal challenges
Flagship policy	R&D tax credit	Collaborative R&D grant	Innovation mission
Key indicator	Level of investment in R&D	Collaboration between university and industry	Emergence, diffusion and impact of new technologies
Data sources	Business surveys, scientometric indicators (patents, publications)	Innovation surveys Knowledge exchange surveys	Text and network data from open and web data
Outputs	Indicators	Scoreboards	Innovation maps

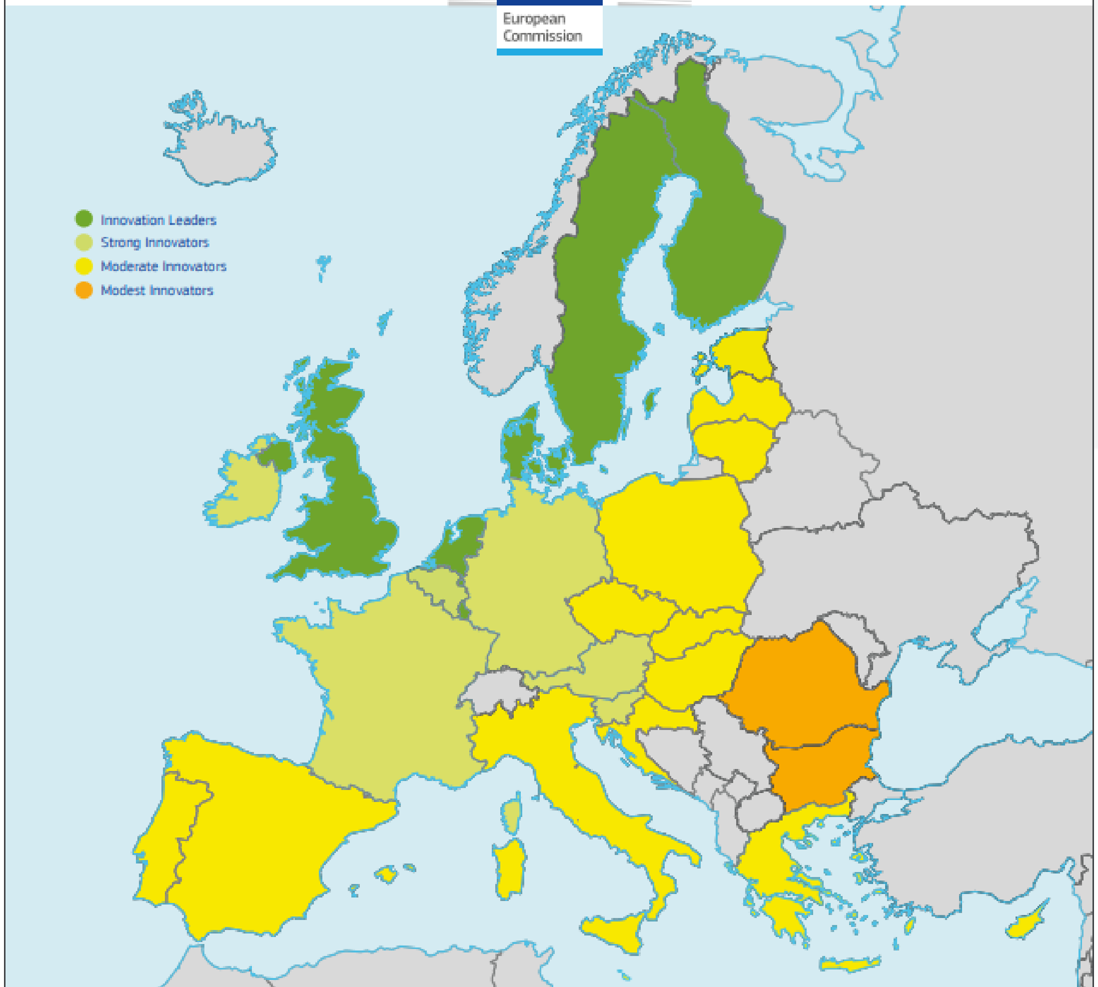
Source: NESTA, Innovation Mapping Now (2019)

Analytical models and STI system performance contexts

	Market failure	System failure	Emergence failure
Rationale for policy	Insufficient investment in R&D because its benefits are not fully captured by the firms carrying it out	Disconnections between researchers and industry due to differences in culture, goals and values	Uncertainty and complexity hinder the application of new technologies to tackle societal challenges
Flagship policy	R&D tax credit	Collaborative R&D grant	Innovation mission
Key indicator	Level of investment in R&D	Collaboration between university and industry	Emergence, diffusion and impact of new technologies
Data sources	Business surveys, scientometric indicators (patents, publications)	Innovation surveys Knowledge exchange surveys	Text and network data from open and web data
Outputs	Indicators	Scoreboards	Innovation maps

Source: NESTA, Innovation Mapping Now (2019)

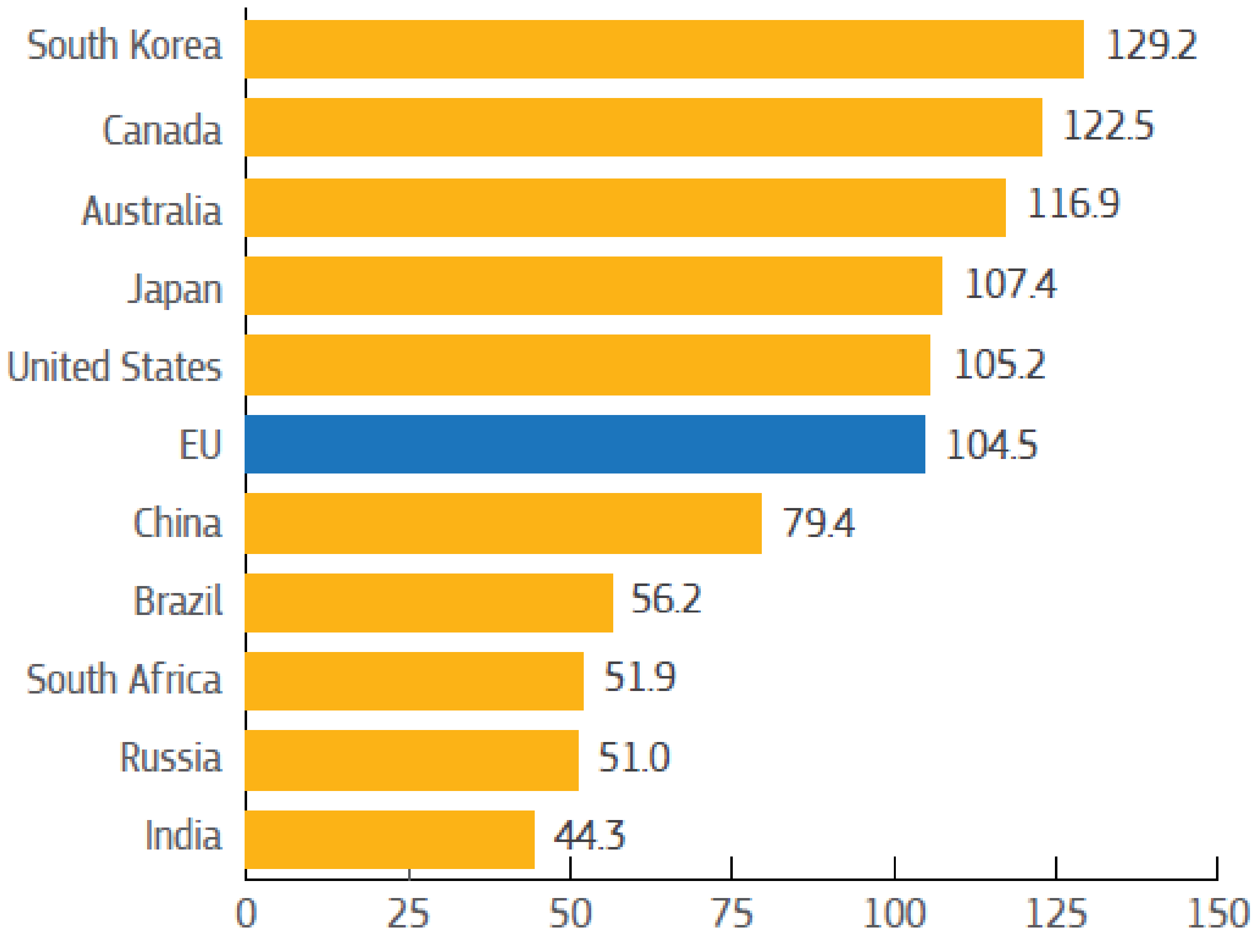
European Commission



European **Innovation Scoreboard** 2018

Innovation

Figure 13: Global performance



Bars show countries' performance in 2017 relative to that of the EU in 2010.

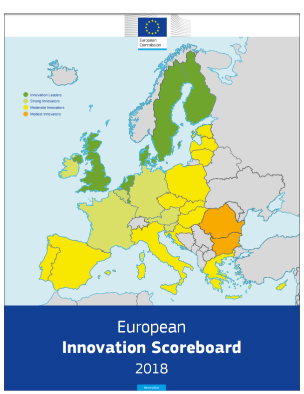


Table 1: Measurement framework of the European Innovation Scoreboard

FRAMEWORK CONDITIONS

Human resources

1.1.1 New doctorate graduates
1.1.2 Population aged 25-34 with tertiary
1.1.3 Lifelong learning

Attractive research systems

1.2.1 International scientific co-publications
1.2.2 Top 10% most cited publications
1.2.3 Foreign doctorate students

Innovation-friendly environment

1.3.1 Broadband penetration
1.3.2 Opportunity-driven entrepreneurship

INVESTMENTS

Finance and support

2.1.1 R&D expenditure in the public sector
2.1.2 Venture capital expenditures

Firm investments

2.2.1 R&D expenditure in the business sector
2.2.2 Non-R&D innovation expenditures
2.2.3 Enterprises providing training to develop or upgrade ICT skills of their personnel

s innovations
anisational innovations

Linkages

3.2.1 Innovative SMEs collaborating with others
3.2.2 Public-private co-publications
3.2.3 Private co-funding of public R&D expenditures

Intelle

3.3.1
3.3.2
3.3.3

IMPA

Empl

4.1.1
4.1.2 tive sectors

Sales impacts

4.2.1 Medium and high-tech product exports
4.2.2 Knowledge-intensive services exports
4.2.3 Sales of new-to-market and new-to-firm product innovations

indicators of
scientific research performance

partial indicator of
technology upgrading

‘Medium & High-Tech product exports’
(% of total product exports)

Indicator	4.2.1 Exports of medium and high technology products as a share of total product exports
Numerator	Value of medium and high tech exports, in national currency and current prices, including exports of the following SITC Rev.3 products: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88 and 891
Denominator	Value of total product exports
Interpretation	The indicator measures the technological competitiveness of the EU, i.e. the ability to commercialise the results of research and development (R&D) and innovation in international markets. It also reflects product specialisation by country. Creating, exploiting and commercialising new technologies are vital for the competitiveness of a country in the modern economy. Medium and high technology products are key drivers for economic growth, productivity and welfare, and are generally a source of high value added and well-paid employment.
Data source	Eurostat (ComExt) for Member States, UN ComTrade for non-EU countries

Source: European Innovation Scoreboard 2018 – Methodology Report (p. 10/11)

Medium & High-Tech product exports

(% of total product exports)

EIS 2018 scores and Compound Annual Growth Rate (CAGR)

	2010	2011	2012	2013	2014	2015	2016	2017	CARG
USA, Canada, Australia, Japan, South Korea	49	47	48	47	48	51	51	51	**0.5%**
Brazil, China, India, Russia, South Africa	30	28	29	29	32	34	35	34	**1.6%**

R&D performance indicators and MHT product export performance

EIS 2018 scores (in 2010 or 2017) that correlate most with 2017 MHT exports scores across the BRICS economies

	Spearman's rho
Designs (2010)	0.7
Designs (2017)	0.7
Scientific research quality (2010)	0.7
Scientific research quality (2017)	1.0
Patents (2017)	0.8
Public-private research cooperation (2017)	0.7

Are these R&D indicators meaningful analytical tools for monitoring and assessment ?

Working Paper Series

GRINCOH

Growth-Innovation-Competitiveness
Fostering Cohesion in Central and Eastern Europe

Serie 3
Knowledge, Innovation, Technology

Paper No. 3.04

A New Metrics of Technology Upgrading: The Central And East European Countries in a Comparative Perspective

Slavo Radošević*, Esin Yoruk*

* University College London

2015

Technology Upgrading in Emerging Economies: A New Approach to its Measurement, Results and Relationship with the Mainstream Measures [1]

The chapter for the book "*Technology Upgrading and Economic Catch-Up*", edited by Jeong-Dong Lee, Keun Lee, Slavo Radosevic, Dirk Meissner, Nicholas S. Vonortas to be published by Oxford University Press

Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*

Table 1. Categories, components and indicators of Technology Upgrading Index (ITU).

Index	Category	Component	Quantitative Indicators	Source	Year
Jpgrading	A. INTENSITY AND TYPES OF TECHNOLOGY UPGRADING (SCALE)	1. Production capability	1.ISO9001 certificates pmi 2.Trademark applications, resident pmi 3.On the job training Q.5.C	ISO WB WEFGCR	2007-11 avg 2012-13
		2. Technology capability	4.Patents resident applications to national office pmi 5.Patent applications to USPTO pmi 6.Patent applications to EPO pmi 7.Resident's industrial design count pmi	WB WIPO WIPO WIPO	2007-11 avg
		3. R&D capability	8.Business Enterprise Sector R&D expenditures (% of GDP 9.Research and development expenditure (% of GDP) 10.Researchers in R&D pmi 11.Technicians in R&D pmi 12.Scientific and technical journal articles pmi 13.Science citations pmi 14.Quality of scientific research institutions Q.12.02 15.University - industry collaboration in R&D Q.12.04	UNESCO WB ThomsonNSI WEFGCR	2011 2010 2007-11 avg 2012-13


Working Paper Series
GRINCOH
Growth-Innovation-Competitiveness
Fostering Cohesion in Central and Eastern Europe
Serie 3
Knowledge, Innovation, Technology
Paper No. 3.04
A New Metrics of Technology Upgrading: The Central And East European Countries in a Comparative Perspective
Slavo Radošević*, Esin Yoruk*
* University College London
2015

Digging deeper: sophisticated indicators for meso and micro level analysis

Sophisticated quantitative indicators on contributions from science ?

1. University-industry R&D cooperation with local firms

(R&D capability indicator)

Sophisticated quantitative indicators on contributions from science ?

1. University-industry R&D cooperation with local firms

(R&D capability indicator)

2. New science-based technologies

(Technology capability indicator)

Testbed: what is the added value of each indicator in the case of the Brazilian STI system ?

Case study #1:

University-industry research cooperation with local firms

How important is local Brazilian science as a knowledge source for its R&D active industry ?

Is it different compared to other countries ?

R&D and innovation policy contexts

	Market failure	System failure	Emergence failure
Rationale for policy	Insufficient investment in R&D because its benefits are not fully captured by the firms carrying it out	Disconnections between researchers and industry due to differences in culture, goals and values	Uncertainty and complexity hinder the application of new technologies to tackle societal challenges
Flagship policy	R&D tax credit	Collaborative R&D grant	Innovation mission
Key indicator	Level of investment in R&D	Collaboration between university and industry	Emergence, diffusion and impact of new technologies
Data sources	Business surveys, scientometric indicators (patents, publications)	Innovation surveys Knowledge exchange surveys	Text and network data from open and web data
Outputs	Indicators	Scoreboards	Innovation maps

Source: NESTA, Innovation Mapping Now (2019)

Performance indicator

University-business research cooperation

- Reflecting a university's attractiveness as R&D partner
- Partial indicator of academic research commercialisation and innovation potential
- Joint research publications co-authored by academic researchers and R&D staff with a business enterprise affiliation
- Represents productive and successful research partnerships
- Enables international comparative geographical analysis

Analytics #1

***University-business co-publications** (UBCs):*

Number of joint research publications co-authored by academic researchers and R&D staff at a firm

Distance metrics:

Author affiliate addresses used to compute the spatial distance (in km) between university's city of location and that of the partner firm

Analytics #2

Source:

Leiden Ranking - 2018 edition (CWTS *Web of Science* database)

UBC-active universities *(each least 80 UBCs in 2013-2016):*

808 worldwide

9 Brazil

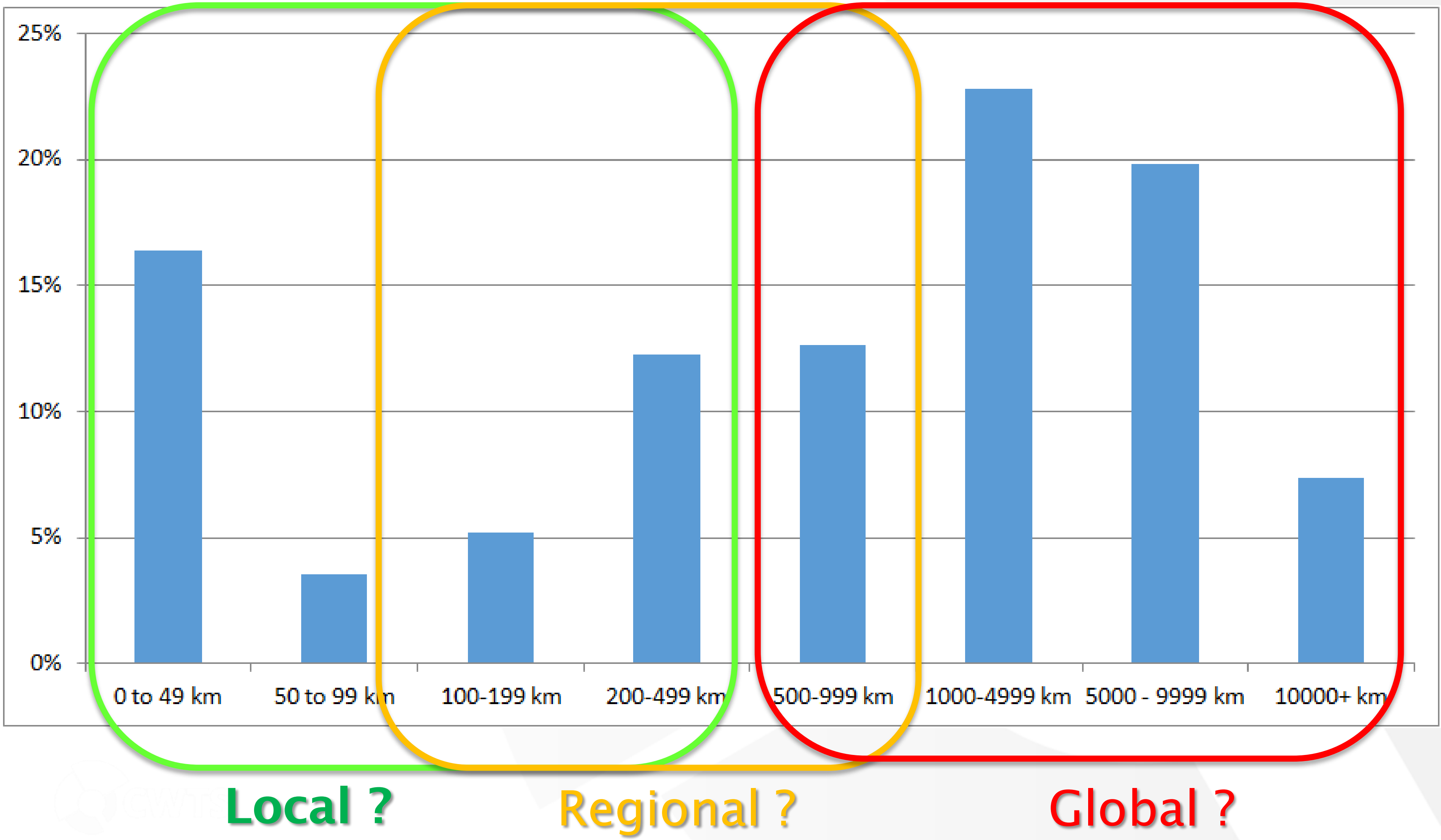
Time-periods:

2013-2016 (recent patterns and profiles)

2008-2017 (compound annual growth rates)

UBC output distribution by distance zone

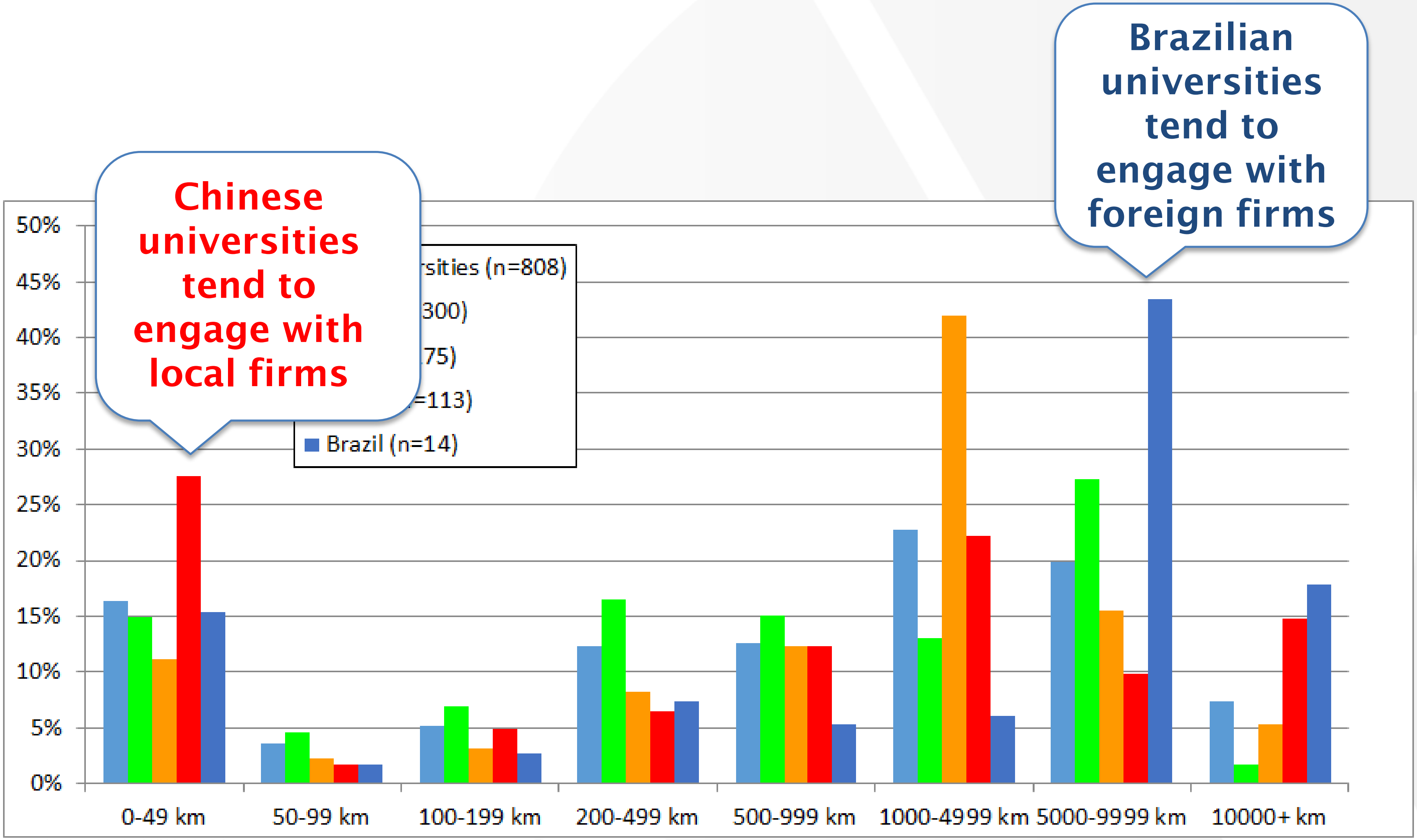
(2013-2017; n=808 universities)



Data source: Web of Science database (CWTS, Leiden University)

UBC output distribution by distance zone

World, EU28, USA, China, Brazil



% ‘0-49 km’ UBCs within total UBC output

Top 10 world’s largest research universities

		UBCs with firms within 50 km (% of all UBCs)	UBCs with firms within 50 km (freq. count)
Seoul National University	South Korea	58%	3 405
The University of Tokyo	Japan	50%	3 884
University of Copenhagen	Denmark	46%	2 977
Shanghai Jiao Tong University	China	38%	1 242
Tsinghua University	China	35%	1 257
Fudan University	China	33%	719
Stanford University	United States	31%	2 913
Xi'an Jiaotong University	China	30%	493
Peking University	China	30%	830
University Chinese Acad. Sciences	China	28%	368

Top 10 largest universities worldwide, sorted by declining share of university-business co-publications with firms located in the local region (2014-2017); Research-intensive universities with more than 20,000 research publications in 2014-2017 (CWTS Web of Science database)

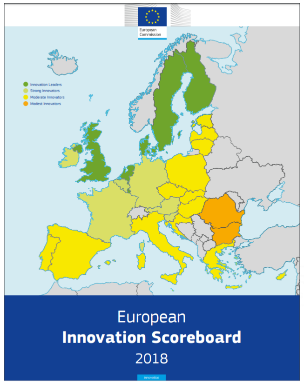
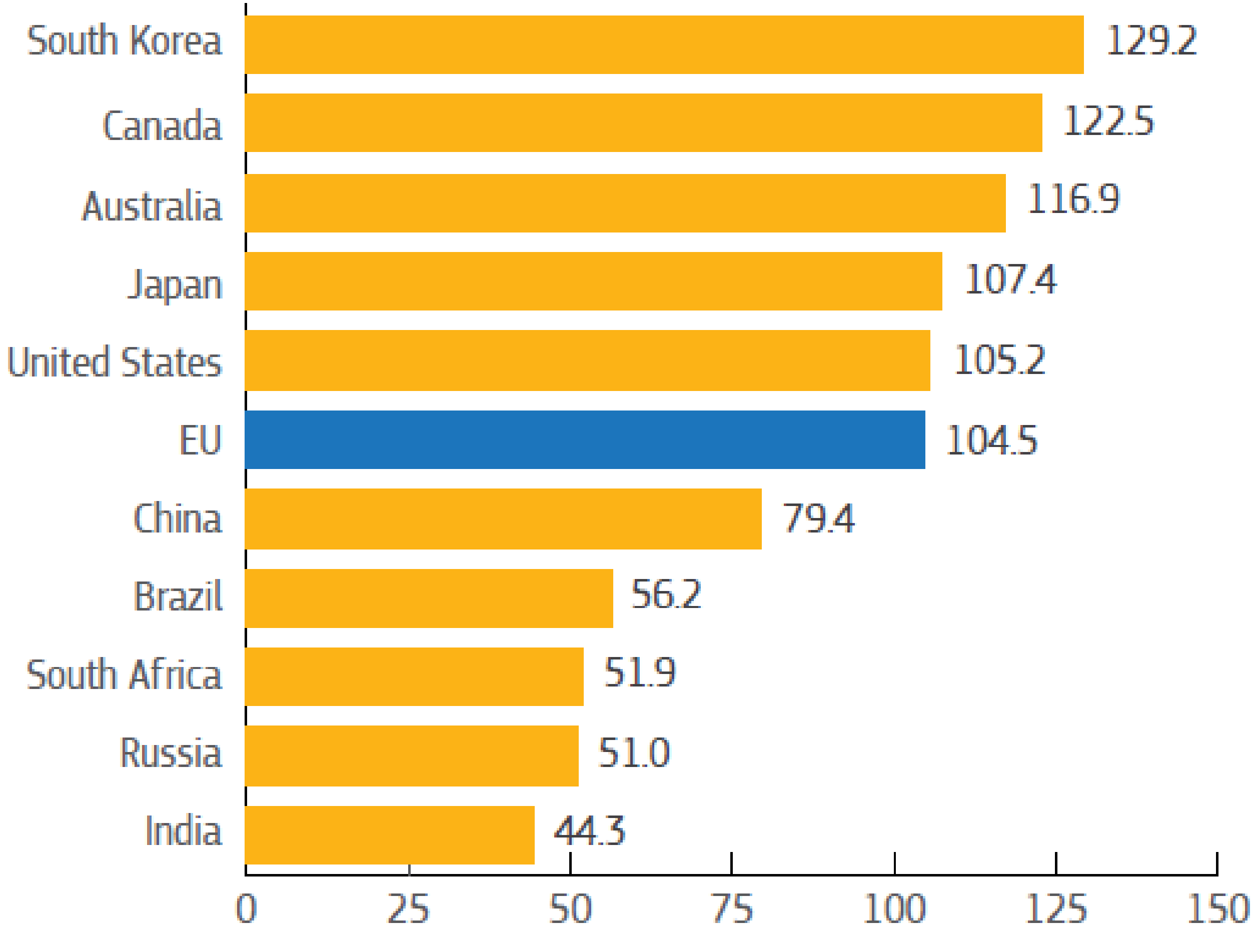
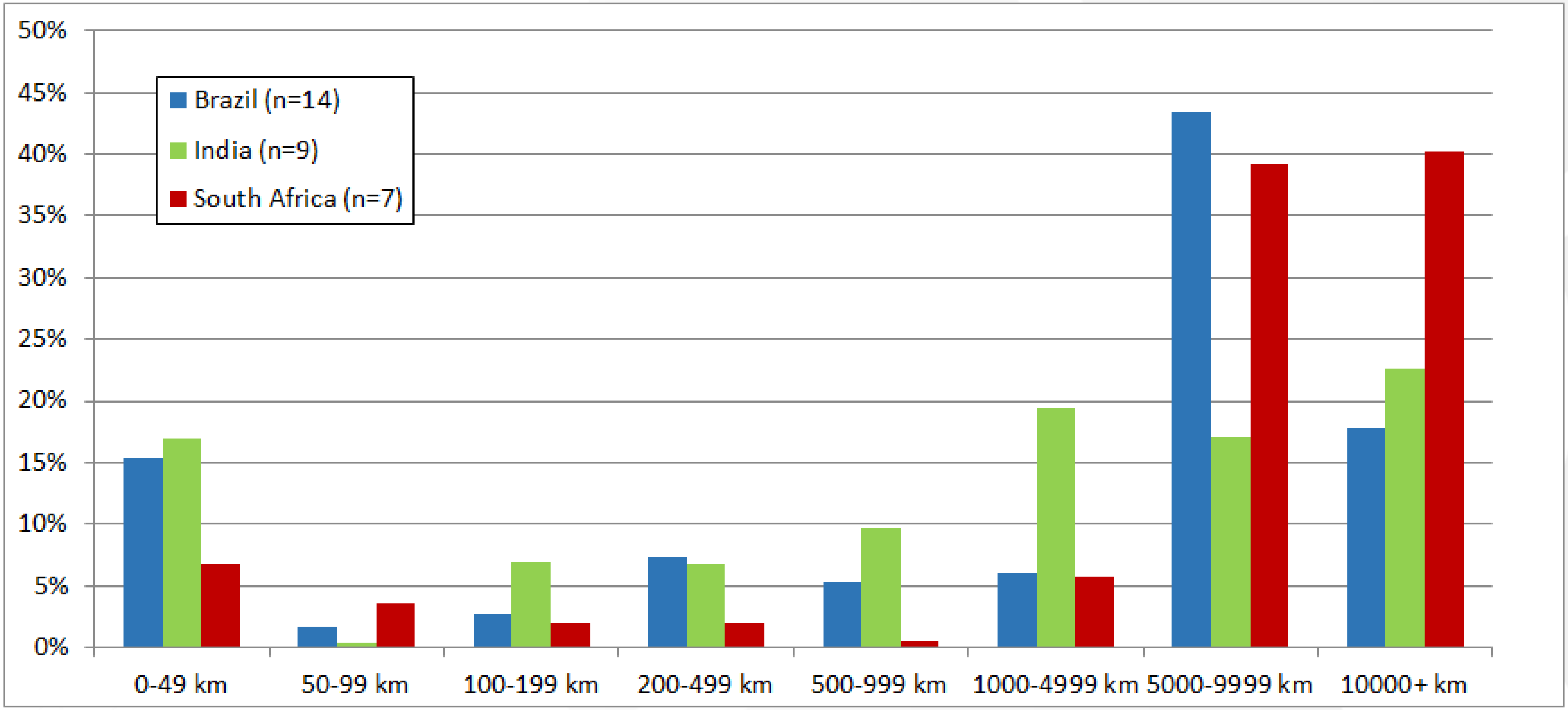


Figure 13: Global performance



Bars show countries' performance in 2017 relative to that of the EU in 2010.

UBC output distribution by distance zone
Brazil, India, South Africa



% ‘0-49 km’ UBCs within total UBC output
Top 5 largest research universities in Brazil

	UBCs with firms within 50 km (% of all UBCs)	UBCs with firms within 50 km (freq. count)
University of São Paulo	13%	135
Universidade Estadual Paulista	12%	25
University of Campinas	9%	30
Universidade Federal do Rio de Janeiro	43%	191
Federal University of Rio Grande do Sul	9%	26

Data source: Web of Science database (CWTS, Leiden University)

% UBCs within total UBC output per university per broad field of science

(2008-2018)

	Biomedical and health sciences	Life and earth sciences	Physical sciences and engineering	Mathematics and computer science	Social sciences and humanities
University of São Paulo	48%	28%	18%	4%	2%
Universidade Estadual Paulista	30%	49%	18%	2%	1%
University of Campinas	32%	24%	34%	9%	1%
Universidade Federal do Rio de Janeiro	24%	23%	43%	8%	2%
Federal University of Rio Grande do Sul	32%	29%	31%	6%	2%

Data source: Web of Science database (CWTS, Leiden University)

% ‘0-49 km’ UBCs within total UBC output per broad field of science

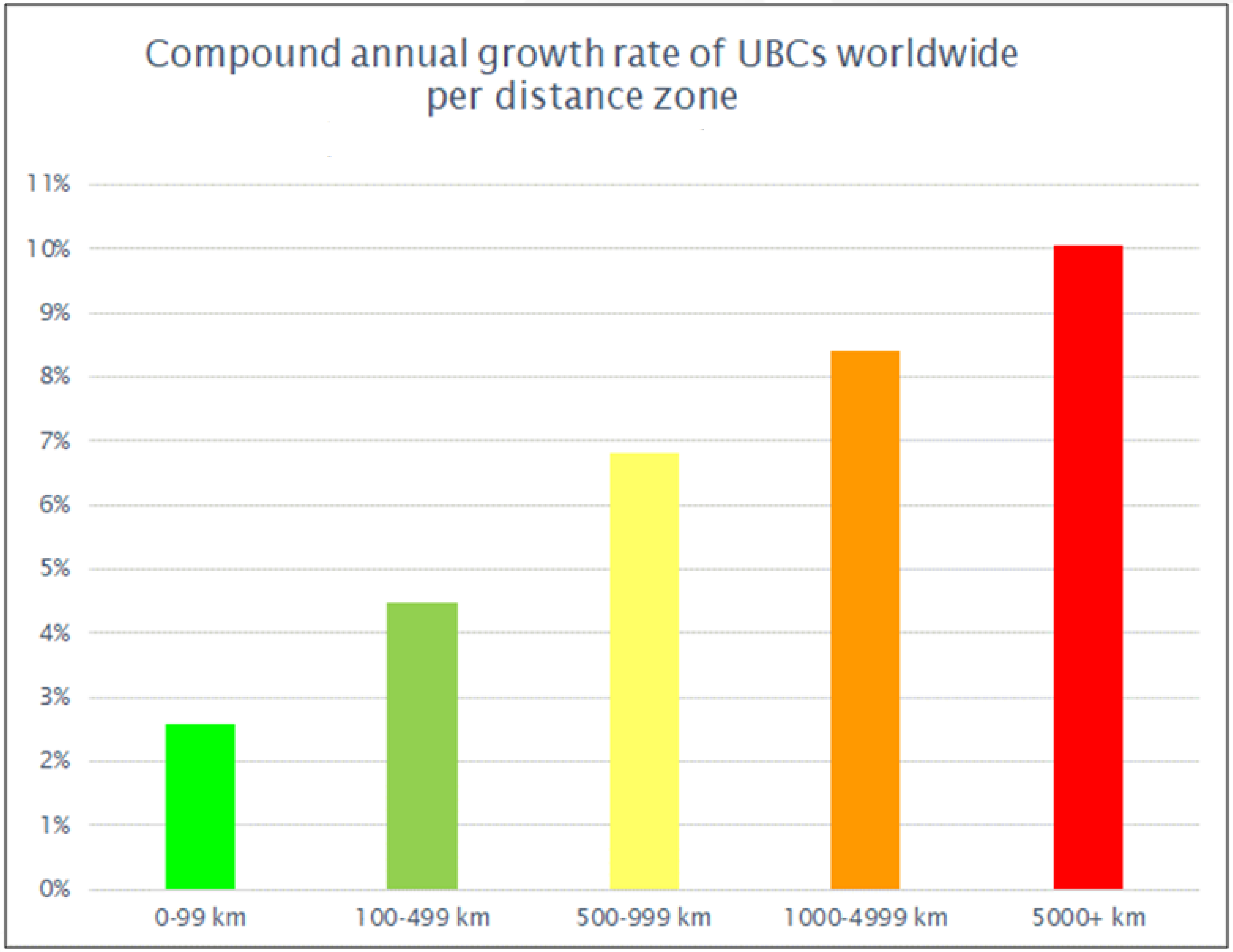
(2008-2018)

	Biomedical and health sciences	Life and earth sciences	Physical sciences and engineering	Mathematics and computer science
University of São Paulo	20%	22%	18%	23%
Universidade Estadual Paulista	12%	14%	13%	7%
University of Campinas	8%	14%	10%	26%
Universidade Federal do Rio de Janeiro	17%	53%	64%	63%
Federal University of Rio Grande do Sul	10%	14%	23%	21%

Data source: Web of Science database (CWTS, Leiden University)

UBC output has increased significantly

(trends 2008-2017; 808 universities worldwide)



Data source: Web of Science database (CWTS, Leiden University)

Growth rates of UBCs per distance zone

(Compound average growth rates, 2008-2017)

	0-99 km	100-499 km	500-999 km	1000-4999 km	5000+ km
University of São Paulo	-2%	1%	-4%	14%	14%
Universidade Estadual Paulista	-4%	3%	-2%	14%	16%
University of Campinas	6%	2%	*nc*	12%	13%
Universidade Federal do Rio de Janeiro	5%	10%	*nc*	9%	10%
Federal University of Rio Grande do Sul	-4%	*nc*	-10%	-2%	-1%

nc – non computable (insufficient data for computation, or zero UBC count in 2008)

Data source: Web of Science database (CWTS, Leiden University)

A small minority of Brazilian university-industry research cooperation involves local firms

Some Brazilian universities have significantly increased that involvement in recent years

Levels of close-distance cooperation is university-specific and field-dependent

A small minority of Brazilian university-industry research cooperation involves local firms

Some Brazilian universities have significantly increased that involvement in recent years

Levels of close-distance cooperation is university-specific and field-dependent

Who are those local companies ?
(university spin-offs, start-ups, large Brazilian firms, subsidiaries of MNEs)

Which (Brazilian) funding (sources) contributed?

Which science-based technologies and patents?

Case study #2:

New science-based technologies

Analytical models and STI system performance contexts

	Market failure	System failure	Emergence failure
Rationale for policy	Insufficient investment in R&D because its benefits are not fully captured by the firms carrying it out	Disconnections between researchers and industry due to differences in culture, goals and values	Uncertainty and complexity hinder the application of new technologies to tackle societal challenges
Flagship policy	R&D tax credit	Collaborative R&D grant	Innovation mission
Key indicator	Level of investment in R&D	Collaboration between university and industry	Emergence, diffusion and impact of new technologies
Data sources	Business surveys, scientometric indicators (patents, publications)	Innovation surveys Knowledge exchange surveys	Text and network data from open and web data
Outputs	Indicators	Scoreboards	Innovation maps

Source: NESTA, Innovation Mapping Now (2019)

Are science-related patents a source of significant change in Brazil's patent portfolio ?

International patents output
Brazil

All DocDB patent families with at least one applicant from Brasil*

Earliest filing year	Patents count: all	Patents count: science-based	% science-based patents
2010	3 844	105	**2.7%**
2011	3 858	110	**2.9%**
2012	3 891	125	**3.2%**
2013	3 611	98	**2.7%**
2014	2 710	85	**3.1%**
2015	1 700	79	**4.6%**

* Data source: PATSTAT database (hosted at CWTS, Leiden University)

Patent-based technology areas in Brazil

(largest areas; share of all ***science-based patents*** > 3%)

	IPC/CPC code	**% all science-related patents (2010-2015)**	Compound average growth rate of share (2010-2015)
Preparations for medical, dental, or toilet purposes	A61K	**14.2%**	-1.4%
Specific therapeutic activity of chemical compounds or medicinal preparations	A61P	**11.3%**	-4.3%
Microorganisms or enzymes; compositions thereof; propagating, preserving, or maintaining microorganisms; mutation or genetic engineering; culture media	C14C	**7.0%**	9.3%
Investigating or analysing materials by determining their chemical or physical properties	G05B	**3.7%**	10.3%
Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture	C21B	**3.3%**	13.4%

Data source: PATSTAT database (CWTS, Leiden University)

Patent-based technology areas in Brazil

(largest areas; share of all science-based patents > 3%)

	IPC/CPC code	% all science-related patents (2010-2015)	Compound average growth rate of share (2010-2015)
Preparations for medical, dental, or toilet purposes	A61K	**14.2%**	**-1.4%**
Specific therapeutic activity of chemical compounds or medicinal preparations	A61P	**11.3%**	**-4.3%**
Microorganisms or enzymes; compositions thereof; propagating, preserving, or maintaining microorganisms; mutation or genetic engineering; culture media	C14C	**7.0%**	**9.3%**
Investigating or analysing materials by determining their chemical or physical properties	G05B	**3.7%**	**10.3%**
Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture	C21B	**3.3%**	**13.4%**

Data source: PATSTAT database (CWTS, Leiden University)

Science-related technology areas represent a small but significant share in Brazil's patent portfolio

Several science-related technology areas are becoming more prominent in that portfolio

Science-related technology areas represent a small but significant share in Brazil's patent portfolio

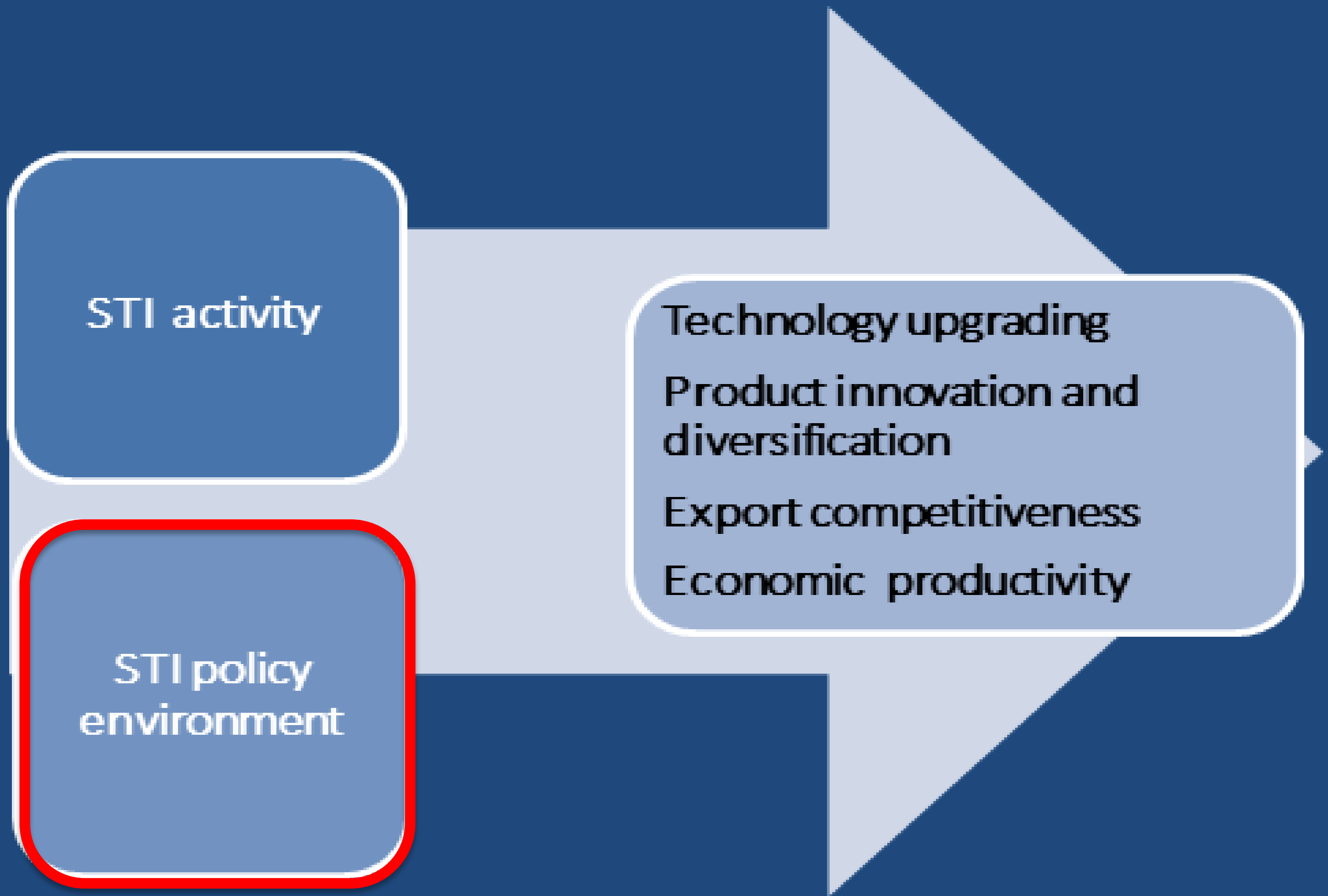
Several science-related technology areas are becoming more prominent in that portfolio

Do these patents reflect technology upgrading?

Which (Brazilian) funding (sources) contributed to the technological development?

Are there related patent-based economic activities?

General lessons and next steps


STI activity
STI policy environment
Technology upgrading
Product innovation and diversification
Export competitiveness
Economic productivity

High-quality measurements

and quantitative performance indicators

provide relevant empirical inputs and

evidence for STI analysis, policy debate

and decision making …

… supplementary to expert opinion,

stakeholder consultation,

or other sources of information

Moving forward:
Evidence-based STI policy and ‘Big Data’

- **Sophisticated indicators + empirical data** provide new insights and offer opportunities for in-depth comparative analysis of STI activities
- **STI analytics** requires large-scale, quantitative approaches for collecting and assessing data on STI inputs, processes, outputs and impacts
- **STI performance indicators** should capture key data and should contextualize information

STI indicators 2.0

- Indicators are theoretically and empirically **underdeveloped**
- **Insufficient** data sources (incomplete; inaccurate)
- **Unreliable** information (subjectivity; time-dependent; partial validity; causality problems; attribution problems)
- Information is subject to **different interpretations** and conclusions
- Performance indicators **not sufficiently developed or misaligned** with user requirements
- Applications in **STI policy environments** are needed

Systems-level application test:

university-industry research cooperation indicator

CENTRE FOR GLOBAL HIGHER EDUCATION

Centre for Global Higher Education working paper series

Globalisation, localisation and glocalisation of university-business research cooperation: general patterns and trends in the UK university system

Robert Tijssen, Wouter van de Klippe and Alfredo Yegros

Working paper no. 50
April 2019

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL   Office for Students OfS   Research England

Case study of the 48 largest research-intensive universities in the UK

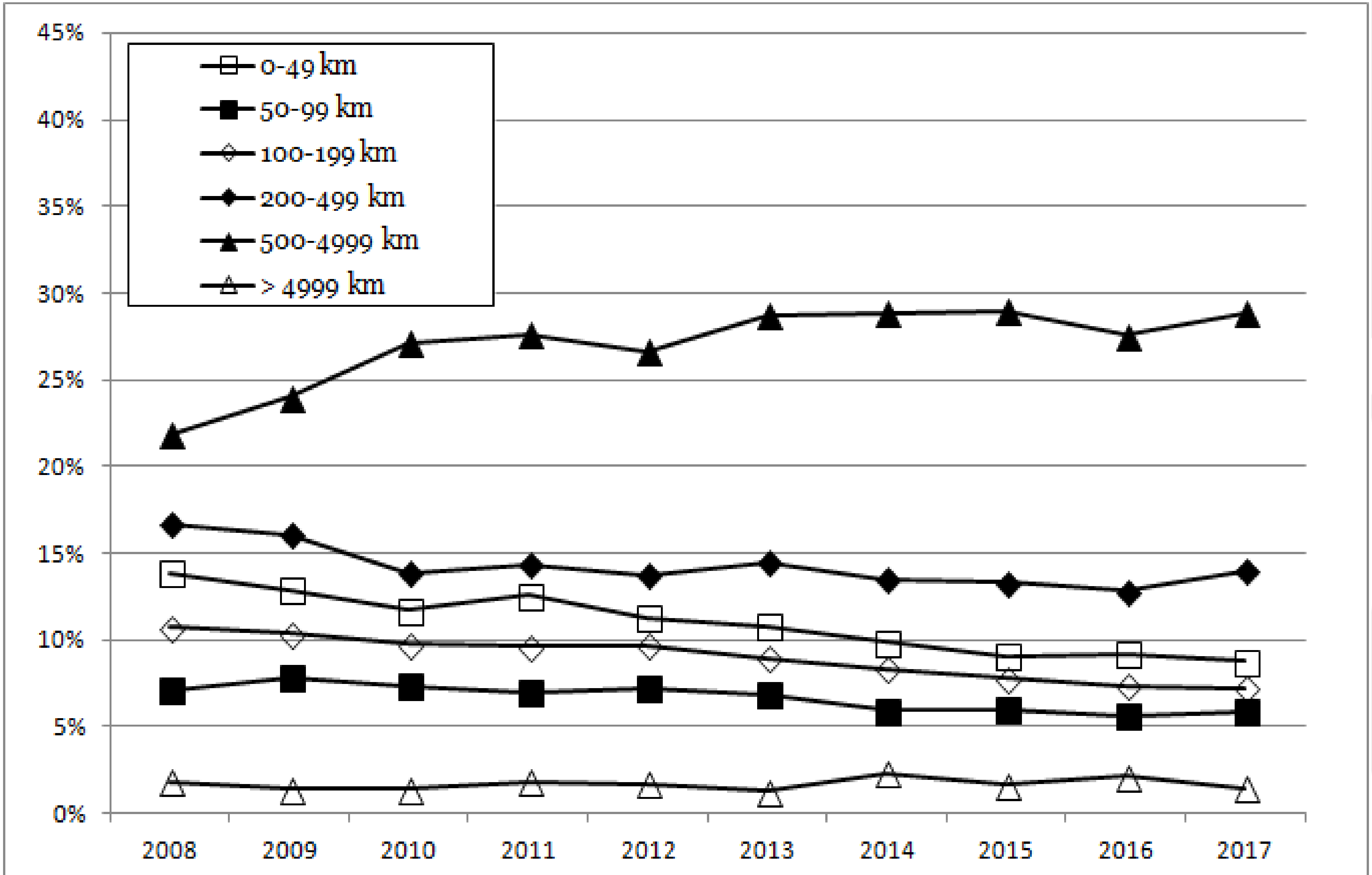
Aggregate-level patterns and trends

Web of Science database (2008-2017)

Table 3. Overview of quantitative information on universities

Performance indicators	Data source (reference year)	Unit of measurement
University-business interactions		
University-business co-publications	Web of Science (2016-2017)	Frequency counts
UBM researchers	Web of Science (2016-2017)	Frequency counts
UB/MA researchers	Web of Science (2016-2017)	Frequency counts
Local R&D environment		
Local business R&D expenditure	UK Office Nat. Statistics (2016)	£ million, 2016
Business sector income streams		
Business sector funding - total	ETER (2014)	Local currency (PPP)
IP revenues – total	HE-BCI (2014/2015)	£ million, 2016
Contract research – SMEs	HE-BCI (2014/2015)	£ million, 2016
Contract research – other (large) firms	HE-BCI (2014/2015)	£ million, 2016
Consultancy – SMEs	HE-BCI (2014/2015)	£ million, 2016
Consultancy - other (large) firms	HE-BCI (2014/2015)	£ million, 2016
Research		
Research publication output – total	Web of Science (2013-2017)	Frequency counts
Publication output – medical fields	Web of Science (2013-2017)	Frequency counts
Publication output – STEM fields	Web of Science (2013-2017)	Frequency counts
Top 10% highly cited publications	Web of Science (2013-2017)	Frequency counts
Technological development, entrepreneurship and innovation		
Inventions - disclosures	HE-BCI (2014/2015)	Frequency counts
Inventions - new applications	HE-BCI (2014/2015)	Frequency counts
Inventions - new patents	HE-BCI (2014/2015)	Frequency counts
Spin-off and start-up firms - new	HE-BCI (2014/2015)	Frequency counts
Spin-off and start-up firms - still active	HE-BCI (2014/2015)	Frequency counts

Annual trends in UBC shares by distance zone (% of total UBC output)



Human Factor indicators

Target: 'Cross-over researchers' employed at universities

Indicator: % of a university's total research publication output (co)produced by :

1. 'University-Business Mobile' researchers (UBM-Rs)
2. 'University-Business Multiple Affiliation' researchers (UB/MA-Rs)

Table A1. University-Business Interactions statistics per university (2008-2017)*

	Publ. output UCB (% total output)	Publ. UBM-Rs (% total output)	Publ. UB/MA-Rs (% of total output)
University of Oxford	8.3	0.8	0.4
University College London	7.7	0.8	0.4
University of Cambridge	9.0	1.6	0.6
Imperial College	11.1	1.3	0.6
University of Manchester	10.0	1.1	0.4
King's College London	8.6	1.0	0.3
University of Edinburgh	8.8	0.9	0.3

Negative binomial regression of UBC output per zone

(statistically significant Wald's chi-square values)

	0-49 km	50-99 km	100-199 km	200-499 km	500-4999 km	> 4999 km
Cross-over researchers						
Cross-sectoral mobile researchers						
Dual affiliation researchers						
Business sector R&D environment						
Local business R&D expenditure						
Business sector income streams						
Contract research - SMEs						
Contract research – large firms						
Consultancy - SMEs						
Consultancy - large firms						
Research						
Research publication output - total						
Publication output – medical fields						
Publication output – STEM fields						
Top 10% highly cited publications						
Technological development, entrepreneurship and innovation						
Inventions - disclosures						
Inventions - new applications						
Inventions - new patents						
Spin-off & start-up firms - new						
Spin-off & start-up firms - active						

Thank you for your attention !

tijssen@cwts.leidenuniv.nl

Table 1. Categories, components and indicators of Technology Upgrading Index (ITU).

Index	Category	Component	Quantitative Indicators	Source	Year
Jpgrading	A. INTENSITY AND TYPES OF TECHNOLOGY UPGRADING (SCALE)	1. Production capability	1.ISO9001 2.Tradem 3.On the	ISO WB WEFGCR	2007-11 avg 2012-13
		2. Technology capability	4.Patents 5.Patent application ...O pmi 6.Patent application 7.Resident's indust	WB WIPO WIPO IPO	2007-11 avg
		3. R&D capability	8.Business Enterpr 9.Research and de 10.Researchers in 11.Technicians in R 12.Scientific and te 13.Science citations p 14.Quality of scientific research institutions Q.12.02 15.University - industry collaboration in R&D Q.12.04	NESCO B ThomsonNSI WEFGCR	2011 2010 2007-11 avg 2012-13

science-based patents signify advanced R&D-intensive technological capabilities and technology upgrading

research cooperation with local industry signifies joint R&D capabilities and knowledge exchange

Sophisticated indicators + empirical data provide new insights and offer opportunities for in-depth comparative analysis of STI activities

Source: Radošević, S. and Esin Yoruk, E. (2015) "A New Metrics of Technology Upgrading: The Central and East European Countries in a Comparative Perspective"

UBC output distribution by distance zone

BRICS vs non-BRICS countries

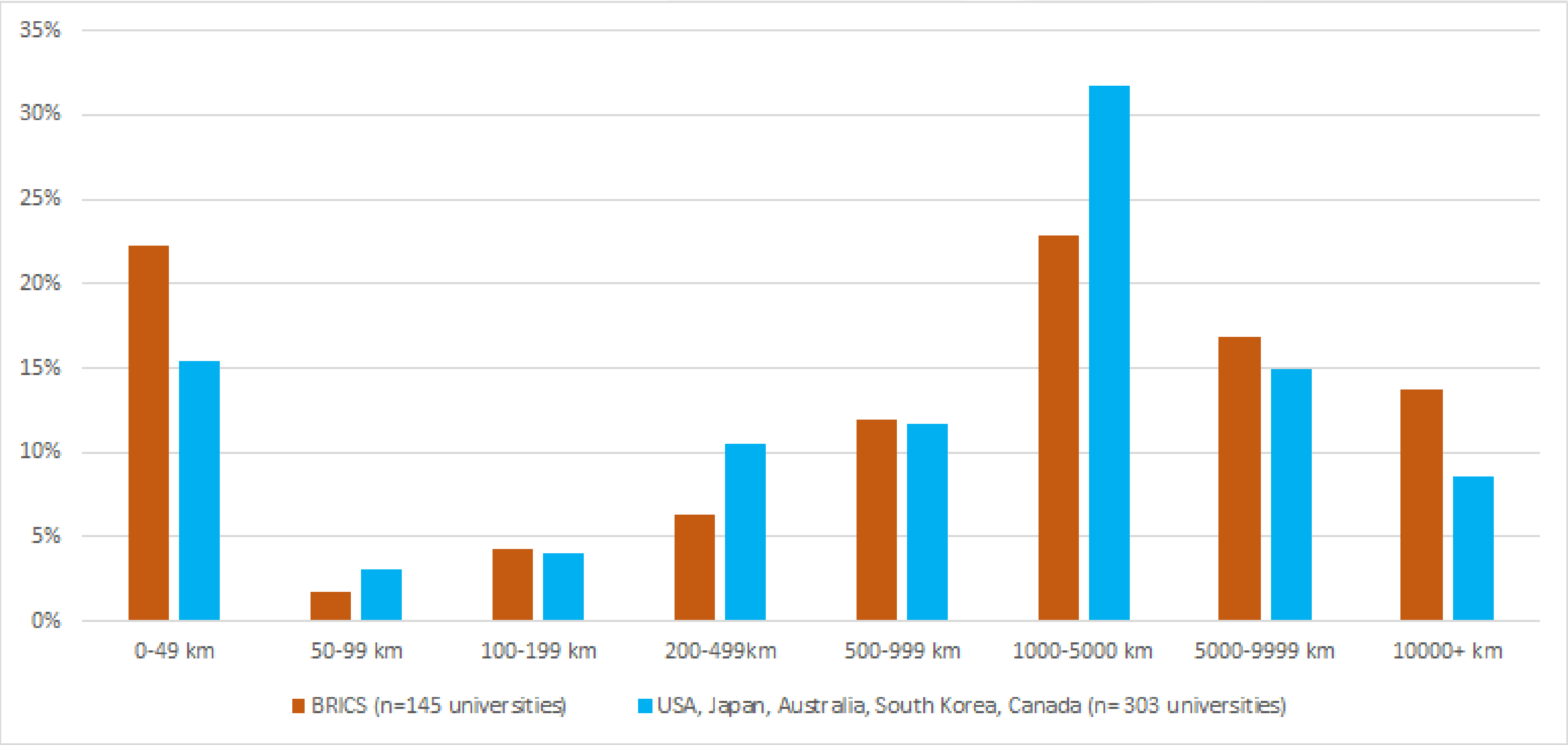
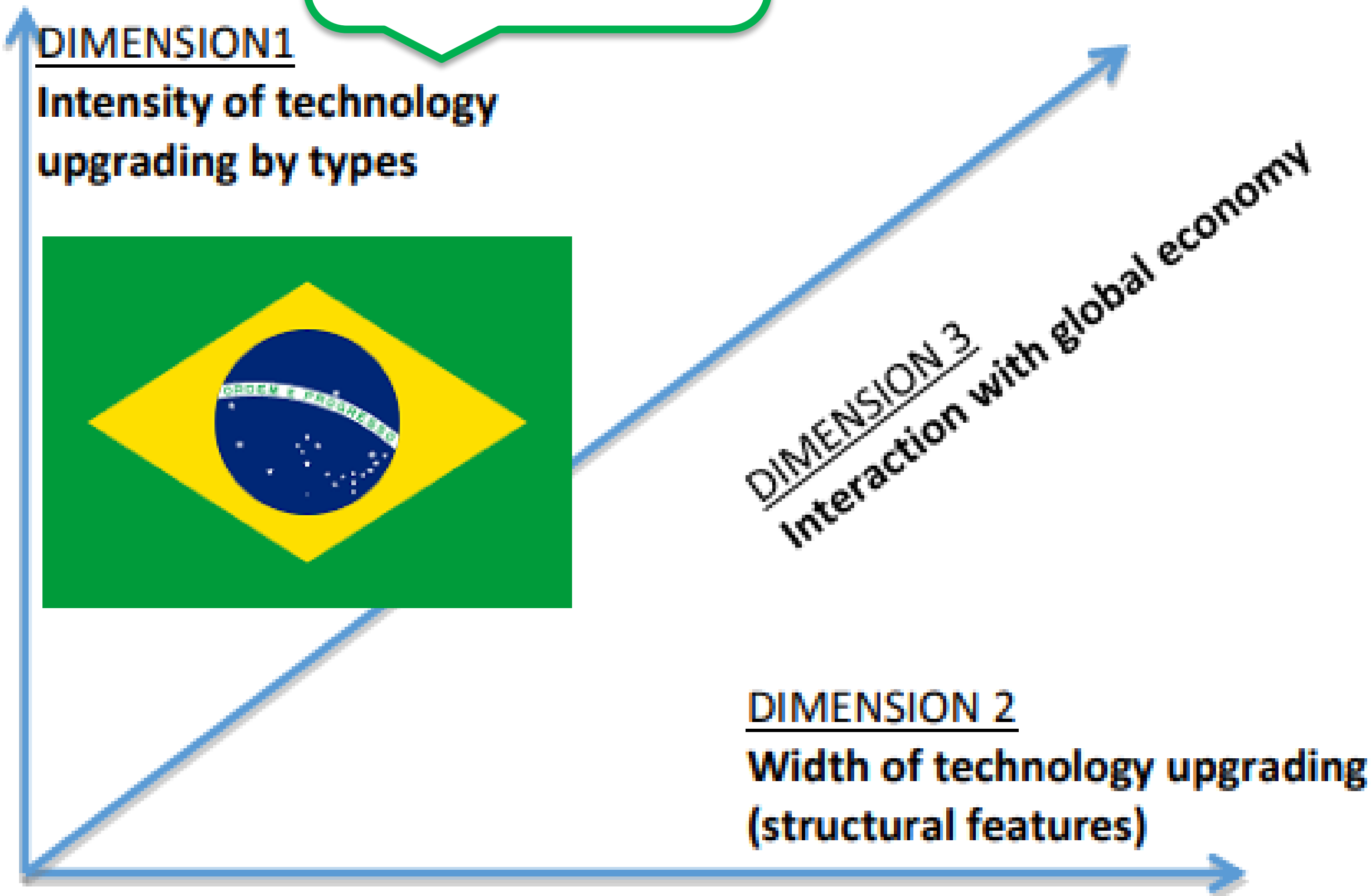


Figure 1: Dimens... rading

What have we learnt from these case studies?



Source: Radošević, S. and Esin Yoruk, E. (2015)
"A New Metrics of Technology Upgrading: The Central and East European Countries in a Comparative Perspective"

Table 1: Components of technology upgrading

Index A: Technology Intensity (scale)
Production Capabilities
R&D Capabilities
Technology Capabilities
Index B: Structural Features (scope/breadth)
Infrastructure (IT, human, physical, organisational)
Knowledge diversification and changes of supply and demand for technology
Organisational capabilities
Index C: Interactions with the Global Economy
Technology and knowledge exchange

Technology Upgrading in Emerging Economies: A New Approach to its Measurement, Results and Relationship with the Mainstream Measures [1]

The chapter for the book "*Technology Upgrading and Economic Catch-Up*", edited by Jeong-Dong Lee, Keun Lee, Slavo Radosevic, Dirk Meissner, Nicholas S. Vonortas to be published by Oxford University Press

Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*

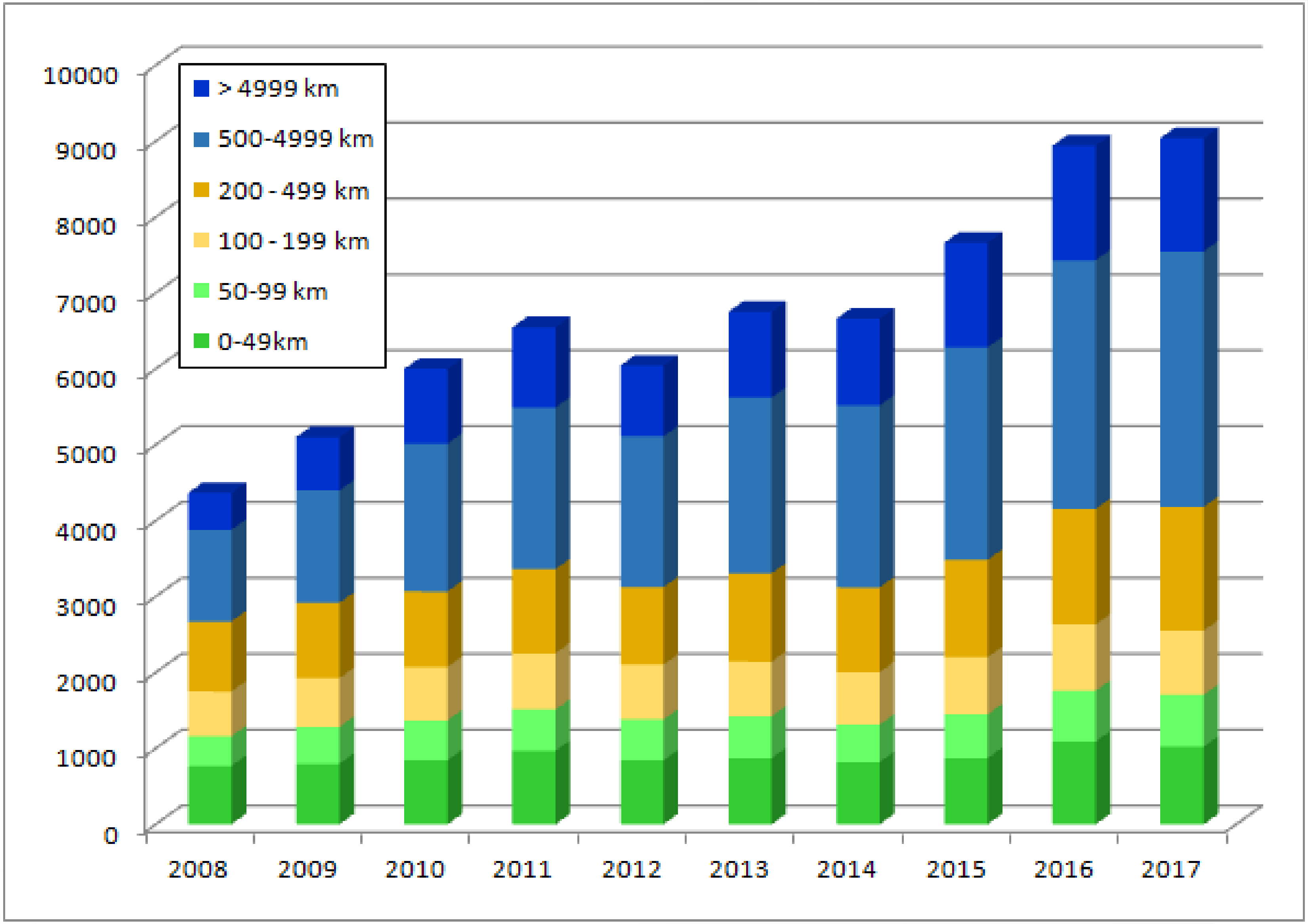
The performance of **Brazil** is below that of the EU, and the country is a Moderate Innovator. Performance has decreased recently. Brazil's relative strengths are in the share of enterprises introducing innovations and Trademark applications.

Performance in 2010 and 2017 relative to EU in 2010

Brazil	2010	2017	2010-2017
Doctorate graduates	24.0	23.4	-0.5
Tertiary education	46.0	43.8	-2.2
International co-publications	46.1	51.5	5.4
Most cited publications	46.0	49.8	3.7
R&D expenditure public sector	91.2	93.3	2.2
R&D expenditure business sector	46.3	41.9	-4.5
Product/process innovators	109.6	114.8	5.3
Marketing/organisational innovators	146.9	181.8	34.9
Innovation collaboration	62.6	52.8	-9.8
Public-private co-publications	5.5	5.6	0.1
Private co-funding public R&D exp.	n/a	n/a	n/a
PCT patent applications	26.0	28.0	2.0
Trademark applications	95.7	99.8	4.0
Design applications	52.0	52.4	0.4
Medium & high tech product exports	39.3	47.3	8.1
Knowledge-intensive services exports	103.9	78.5	-25.5

Best three and worst three indicators highlighted.

Annual trends in UBC output by distance zone



Patent-based technology areas in Brazil

(largest areas; share in all patents > 1.5%)

	IPC/CPC code	**% of all international patents with a Brasilian applicant (2010-2015)**	Compound average growth rate of share (2010-2015)
Preparations for medical, dental, or toilet purposes	A61K	**4.9%**	4.2%
Specific therapeutic activity of chemical compounds or medicinal preparations	A61P	**3.2%**	4.1%
Cranes; load-engaging elements or devices for cranes, capstans, winches, or tackles	B66C	**1.9%**	-5.7%
Investigating or analysing materials by determining their chemical or physical properties	G05B	**1.8%**	10.9%
Electric digital data processing	G10D	**1.8%**	3.5%
Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided for	G11B	**1.5%**	6.7%

* Data source: PATSTAT database (CWTS, Leiden University)

Patent-based technology areas in Brazil

(largest areas; share in all patents > 1.5%)

	IPC/CPC code	**% of all international patents with a Brasilian applicant (2010-2015)**	Compound average growth rate of share (2010-2015)
Preparations for medical, dental, or toilet purposes	A61K	4.9%	4.2%
Specific therapeutic activity of chemical compounds or medicinal preparations	A61P	3.2%	4.1%
Cranes; load-engaging elements or devices for cranes, capstans, winches, or tackles	B66C	1.9%	-5.7%
Investigating or analysing materials by determining their chemical or physical properties	G05B	1.8%	**10.9%**
Electric digital data processing	G10D	1.8%	3.5%
Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided for	G11B	1.5%	**6.7%**

Data source: PATSTAT database (CWTS, Leiden University)

Patent-based technology areas in Brazil

(largest areas; share of all patents > 1.5%)

	IPC/CPC code	**% all science-related patents (2010-2015)**	Compound average growth rate of share (2010-2015)
Preparations for medical, dental, or toilet purposes	A61K	**14.2%**	**-1.4%**
Specific therapeutic activity of chemical compounds or medicinal preparations	A61P	**11.3%**	**-4.3%**
Cranes; load-engaging elements or devices for cranes, capstans, winches, or tackles	B66C	**0.2%**	n.a.
Investigating or analysing materials by determining their chemical or physical properties	G05B	**3.7%**	**10.3%**
Electric digital data processing	G10D	**1.1%**	1.0%
Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided for	G11B	**0.3%**	n.a.

Data source: PATSTAT database (CWTS, Leiden University)

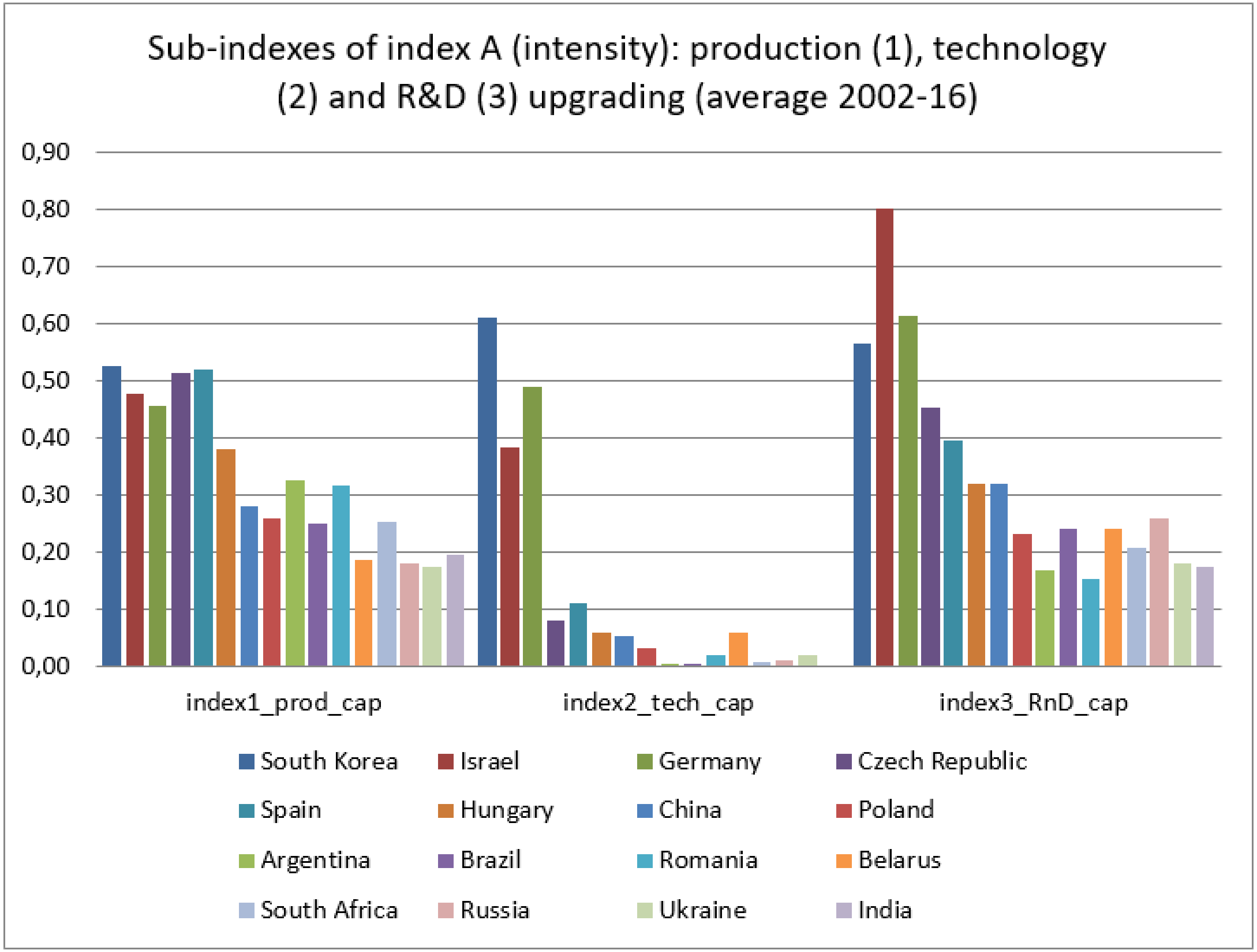
Patent-based technology areas in Brazil

(largest areas; share of all patents > 1.5%)

	IPC/CPC code	**% all science-related patents (2010-2015)**	Compound average growth rate of share (2010-2015)
Preparations for medical, dental, or toilet purposes	A61K	**14.2%**	-1.4%
Specific therapeutic activity of chemical compounds or medicinal preparations	A61P	**11.3%**	-4.3%
Cranes; load-engaging elements or devices for cranes, capstans, winches, or tackles	B66C	**0.2%**	n.a.
Investigating or analysing materials by determining their chemical or physical properties	G05B	**3.7%**	10.3%
Electric digital data processing	G10D	**1.1%**	1.0%
Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided for	G11B	**0.3%**	n.a.

Data source: PATSTAT database (CWTS, Leiden University)

Figure 4 Dissecting Sub-indexed of Index A

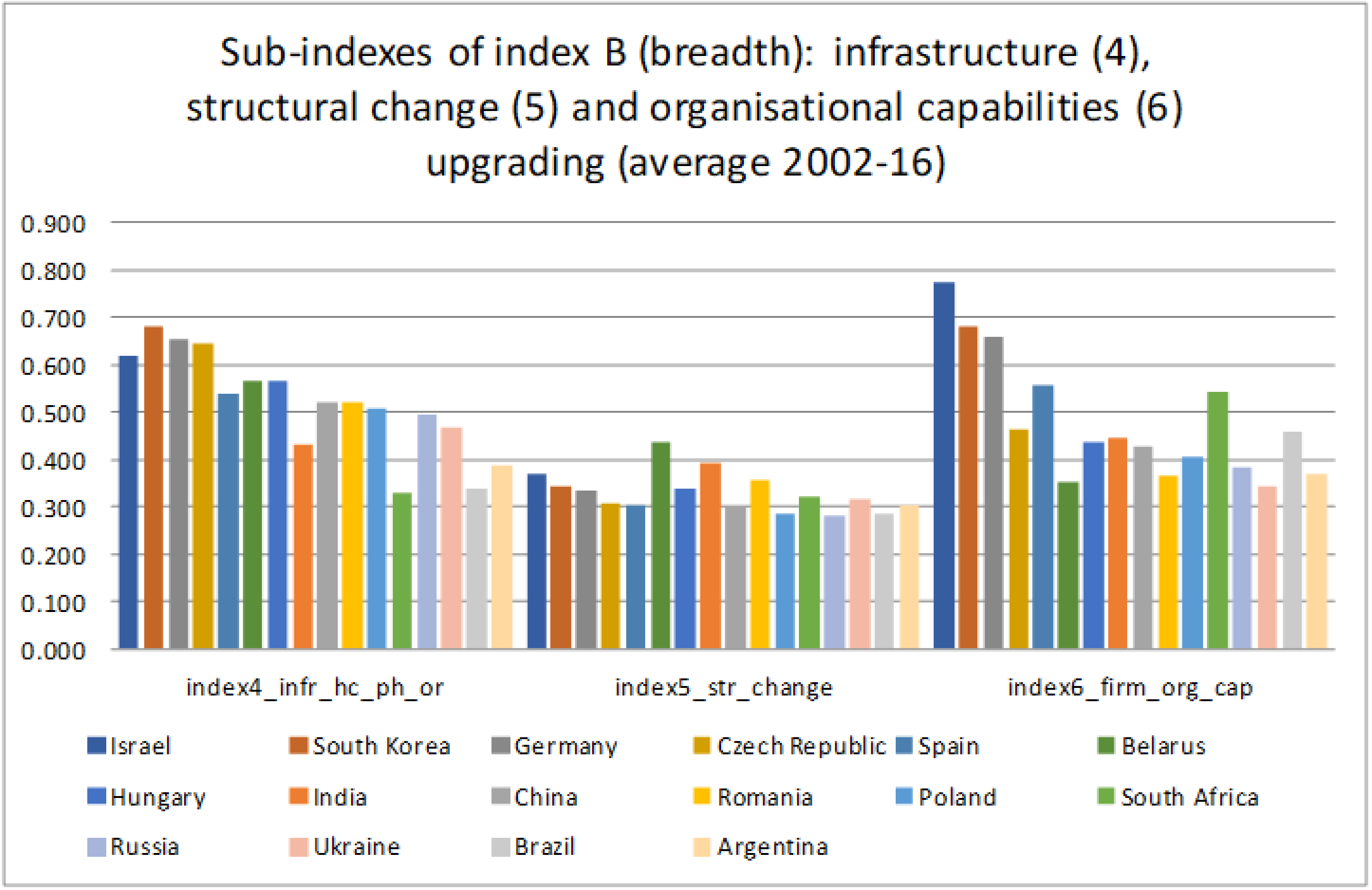


\ New Approach to its
stream Measures [1]

-Up", edited by Jeong-Dong Lee,
e published by Oxford University

Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*

Figure 5 Dissecting Sub-indexed of Index B



New Approach to its
tream Measures [1]

The chapter for the book "*Technology Upgrading and Economic Catch-Up*", edited by Jeong-Dong Lee, Keun Lee, Slavo Radosevic, Dirk Meissner, Nicholas S. Vonortas to be published by Oxford University Press

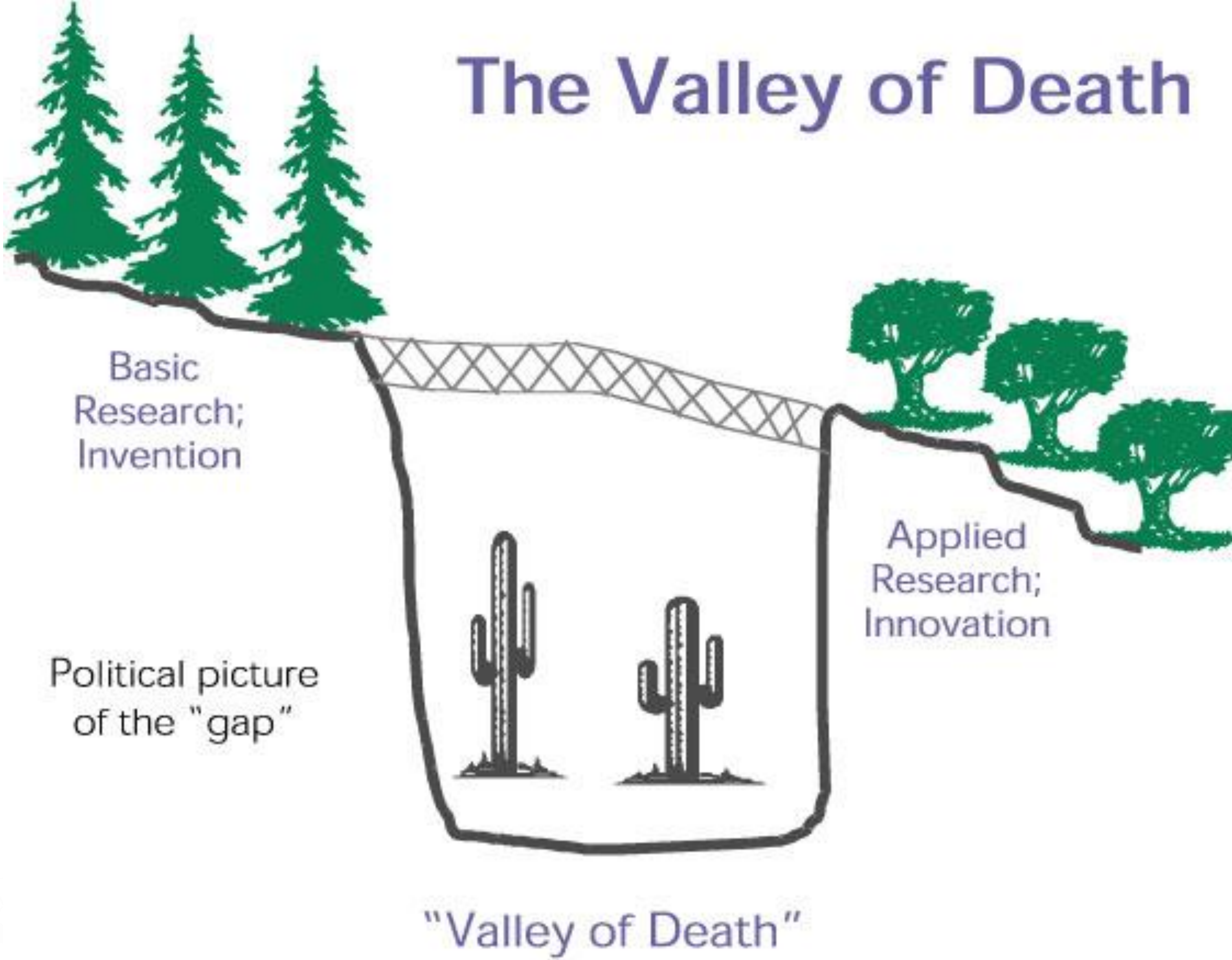
Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*

Medium & High-Tech product exports

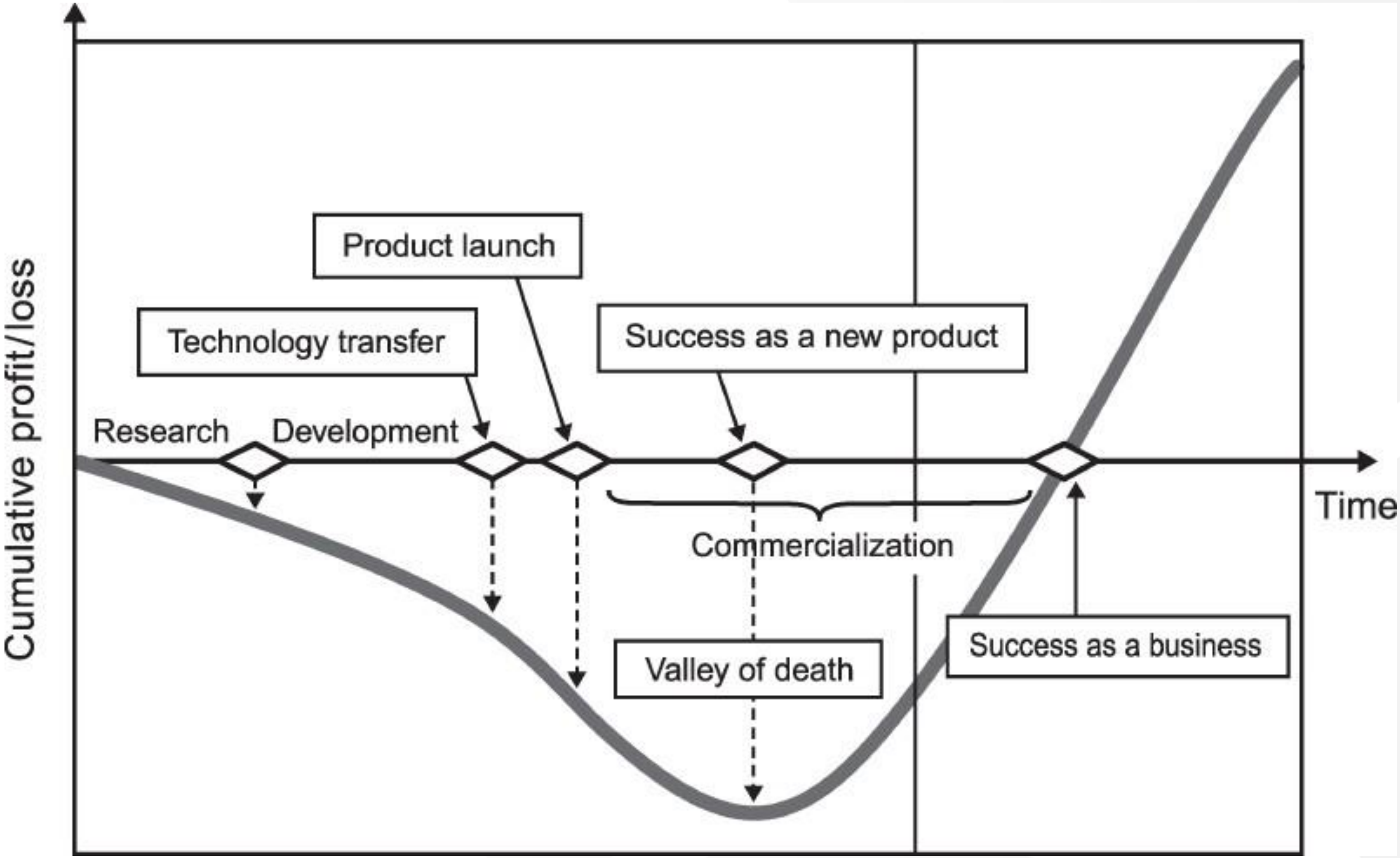
(% of total product exports; EIS 2018 scores)

EIS 2018 scores and Compound Annual Growth Rate (CAGR)

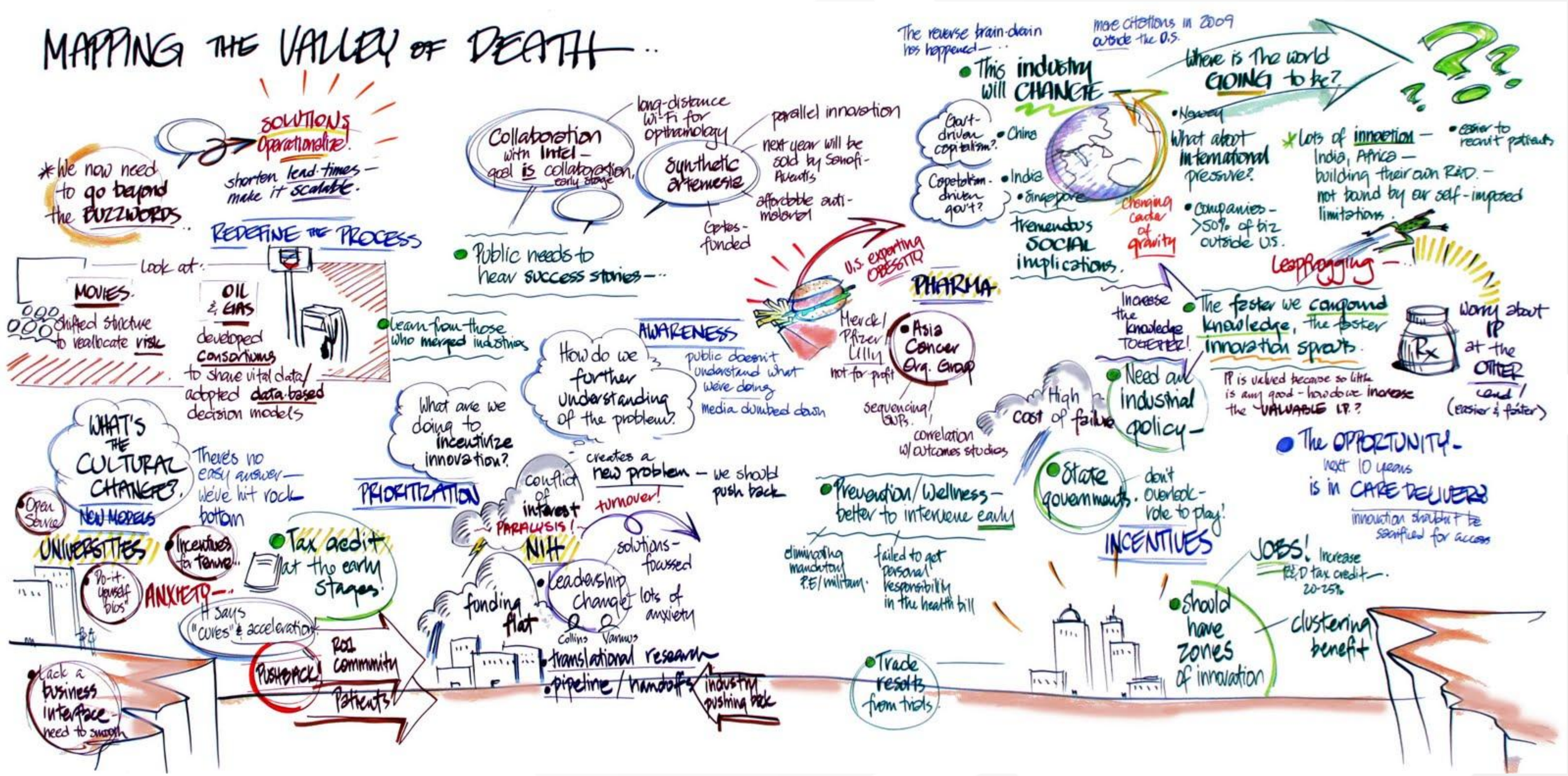
	2010	2011	2012	2013	2014	2015	2016	2017	CARG
Brazil	25	23	24	26	28	30	32	29	**2%**
China	58	57	56	56	55	56	57	57	**0%**
India	26	24	25	25	28	31	32	32	**3%**
Russia	9	8	10	10	10	13	13	13	**5%**
South Africa	33	28	30	30	36	39	39	39	**2%**



Source: www.linkedin.com (killing-messenger-4-ways-assassinate-competitions-khalid-al-haribi)

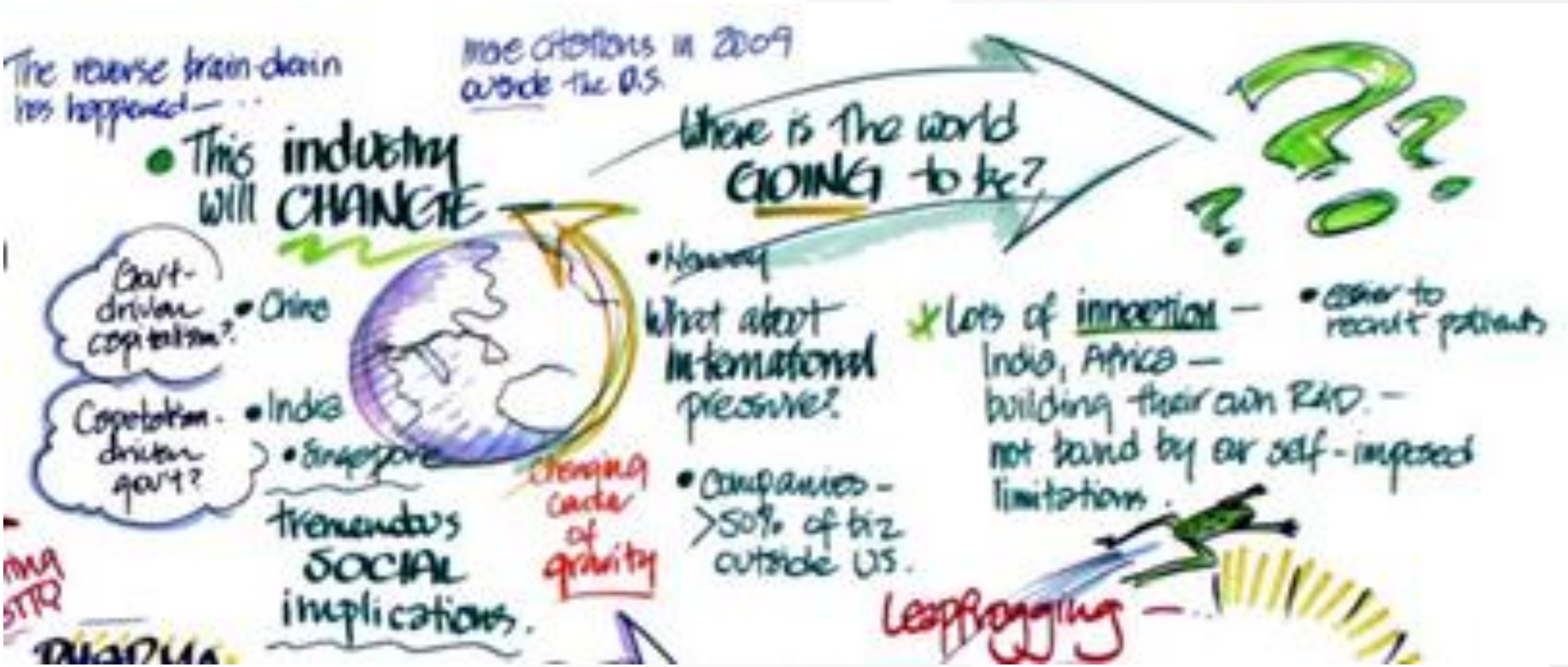


Source: www.forbes.com (10-ways-for-startups-to-survive-the-valley-of-death)

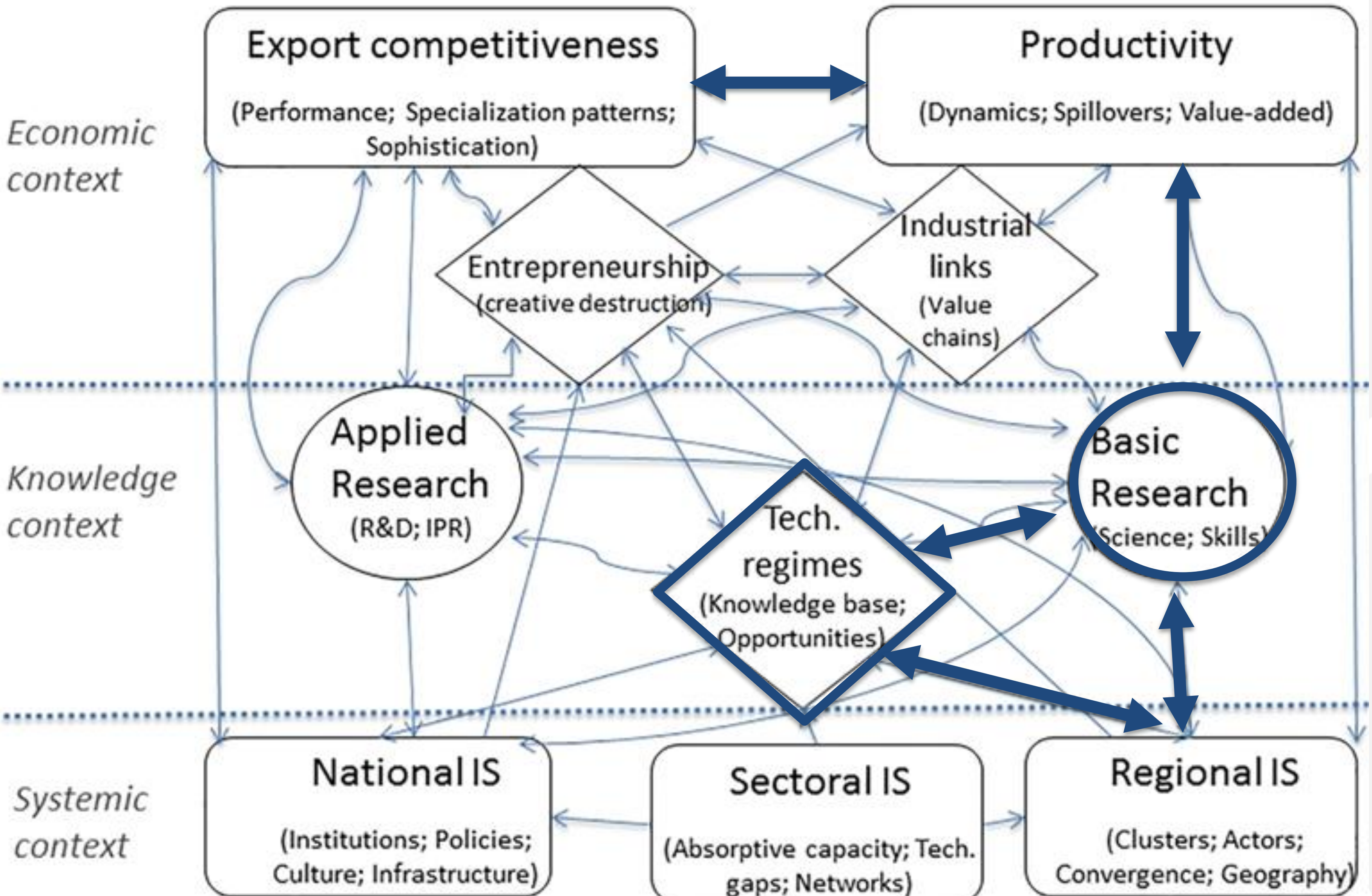


Source: Fastercures.blogspot.com (are-we-there-yet-navigating-path)

Source: Fastercures.blogspot.com (are-we-there-yet-navigating-path)



Source: Fastercures.blogspot.com (are-we-there-yet-navigating-path)



Adapted from: Krammer (Technological forecasting and Social Change, 2017)

Complex system with interacting determinants

Organisational:

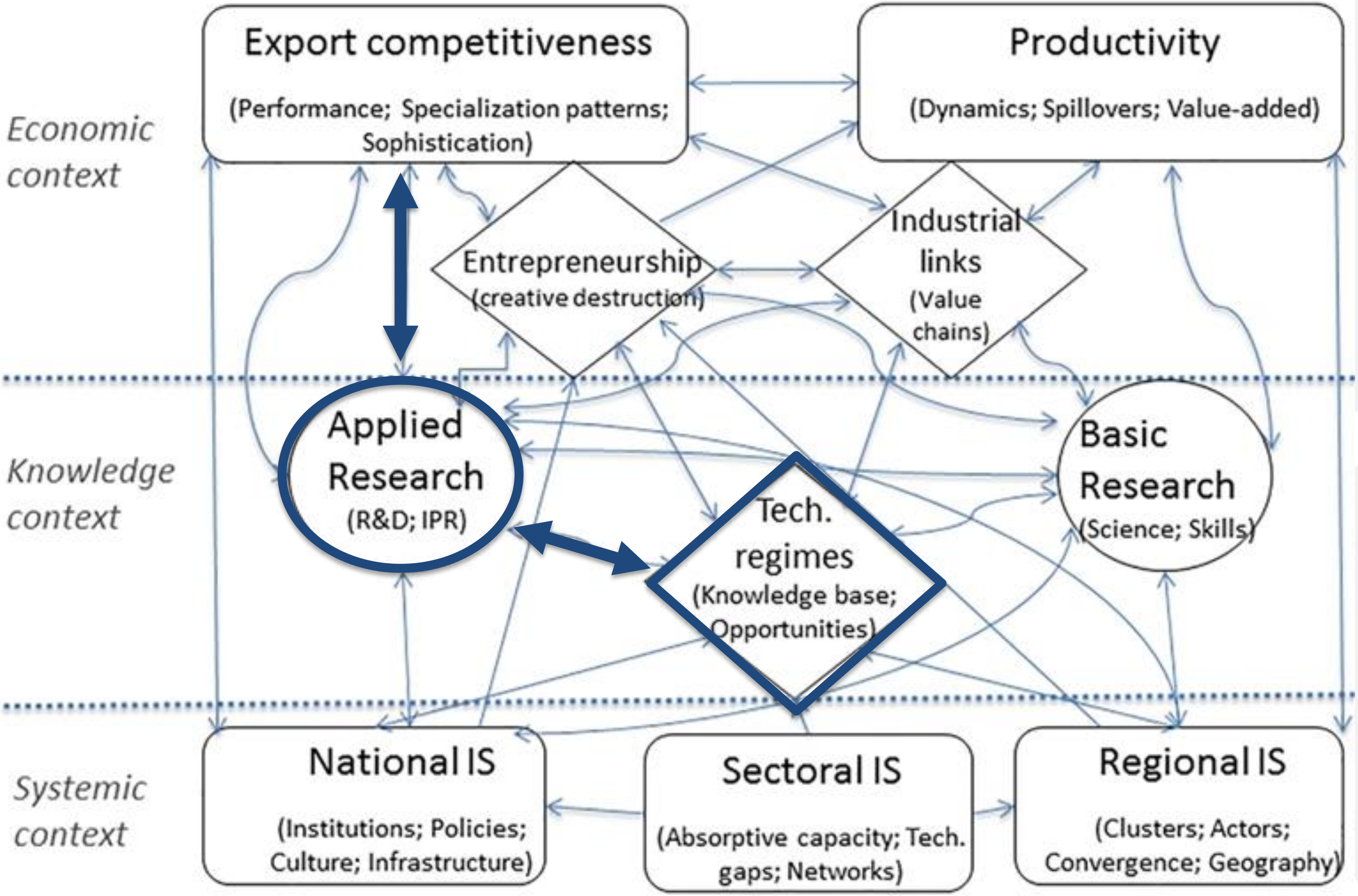
- Strategies; resources; infrastructure; knowledge management
- R&D specialization; competitive environment; critical mass of attractive assets; economies of scale and scope
- Incentive systems and organisational culture

Geographical:

- Located in areas with high levels of R&D activity and connectivity (metropolitan areas; economic hot spots)
- Differential proximity effects

General framework conditions:

- Alignment between knowledge supply (university) and knowledge demand (industry)
- Support systems and transfer structures (co-creation processes and open science, open innovation)
- Local, regional or domestic policies and funding instruments



Adapted from: Krammer (Technological forecasting and Social Change, 2017)

POLICY FORUM

RESEARCH FUNDING

Government-funded research increasingly fuels innovation

Nearly a third of U.S. patents rely directly on federal research

By **L. Fleming[1], H. Greene[2], G. Li[1], M. Marx[3], D. Yao[4]**

Innovation increasingly relies on scientific knowledge (*1, 2*). Research to generate that knowledge has historically been funded by both industry and government. Although industry and government research spending was rel- inventors since 1926, and show that the proportion of patents relying on federally funded science has outstripped the overall increase in patenting, plateauing since a high of 30.0% in 2011 (see the first figure). Despite this plateau, the absolute number of patents that rely on federally supported research has almost doubled recently, from 22,647 in 2008 to 45,220 in 2017. We count

Science, 21 JUNE 2019 • VOL 364 ISSUE 6446, 1139-1141

Patentees increasingly depend upon federally supported research

Total granted U.S. patents by U.S. inventors (blue bars), and subtotal that rely on federal research (orange bars), and proportion of patents (black line = orange bars/blue bars) that rely on federally supported research.

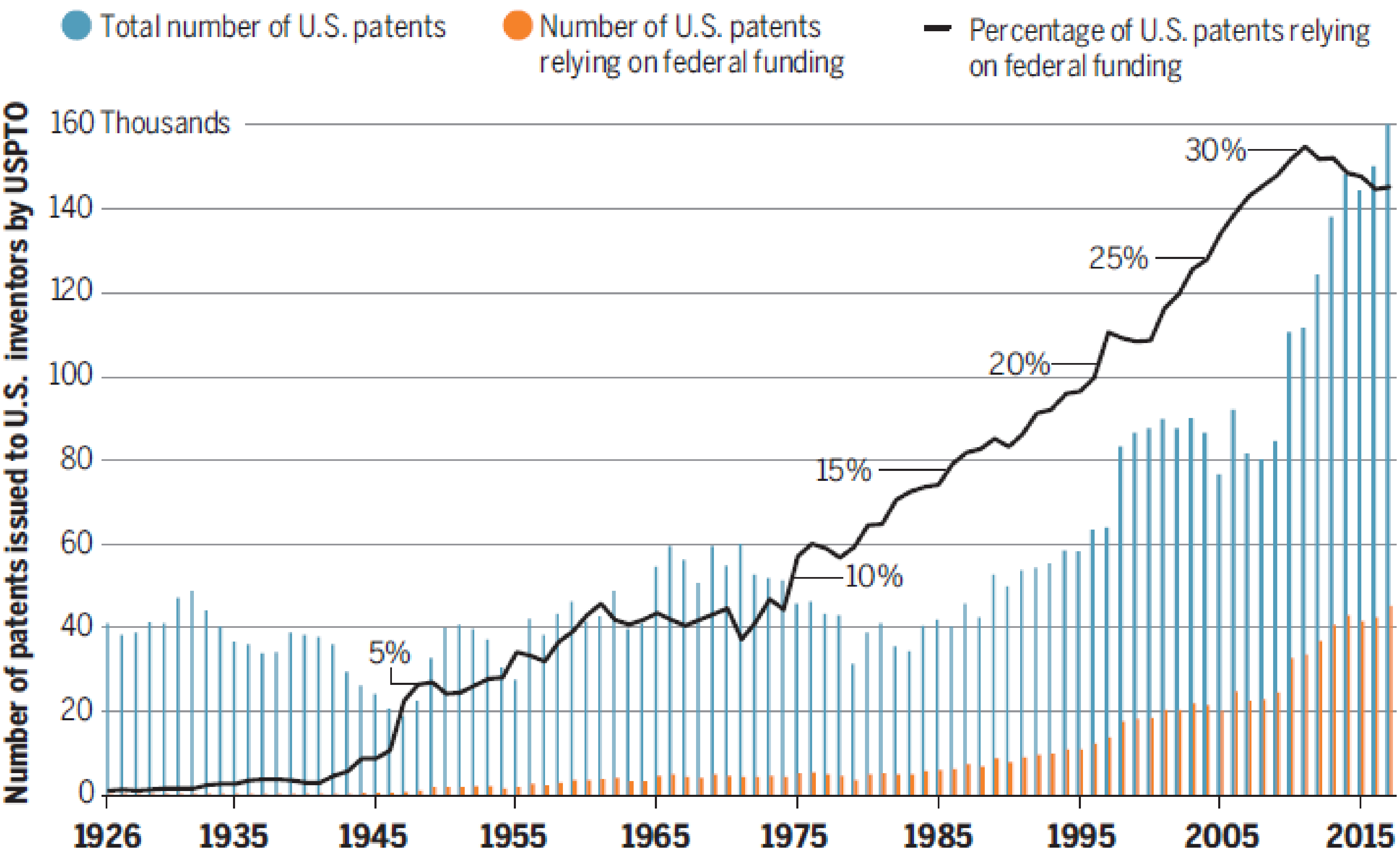
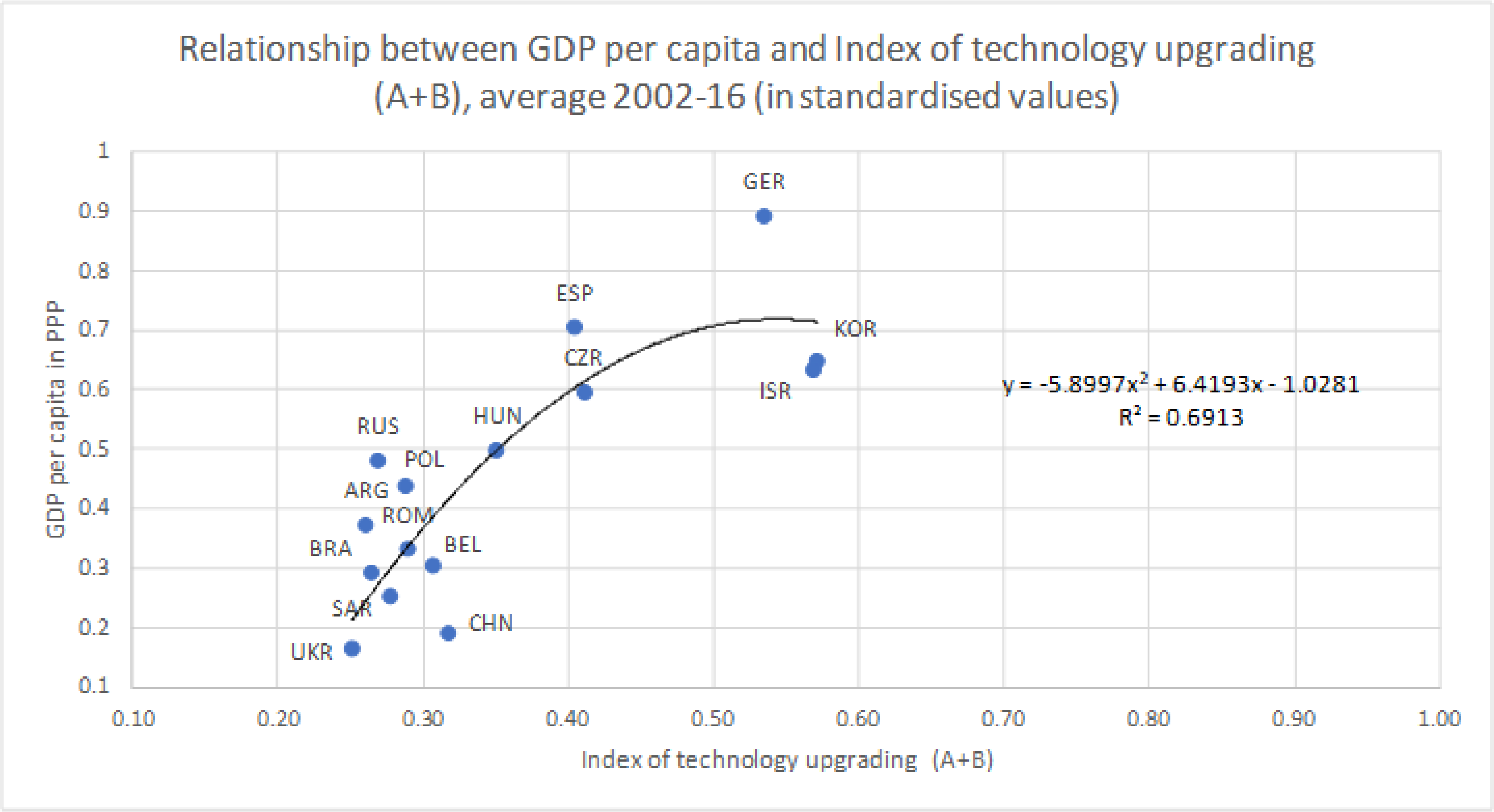


Figure 1: GDP per Capita and Index of Technology Upgrading

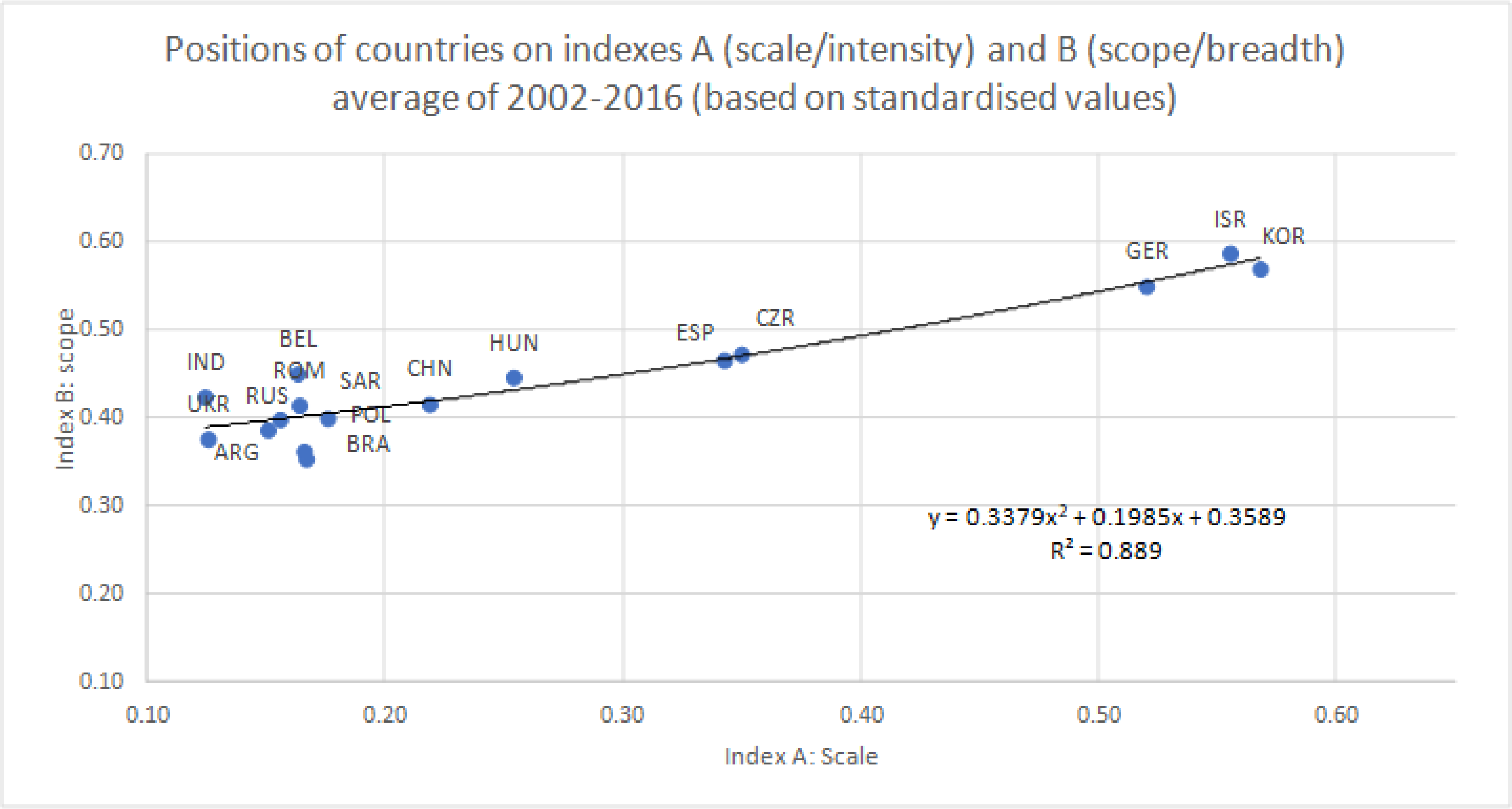


Technology Upgrading in Emerging Economies: A New Approach to its Measurement, Results and Relationship with the Mainstream Measures [1]

The chapter for the book "*Technology Upgrading and Economic Catch-Up*", edited by Jeong-Dong Lee, Keun Lee, Slavo Radosevic, Dirk Meissner, Nicholas S. Vonortas to be published by Oxford University Press

Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*

Figure 2: Index A and Index B

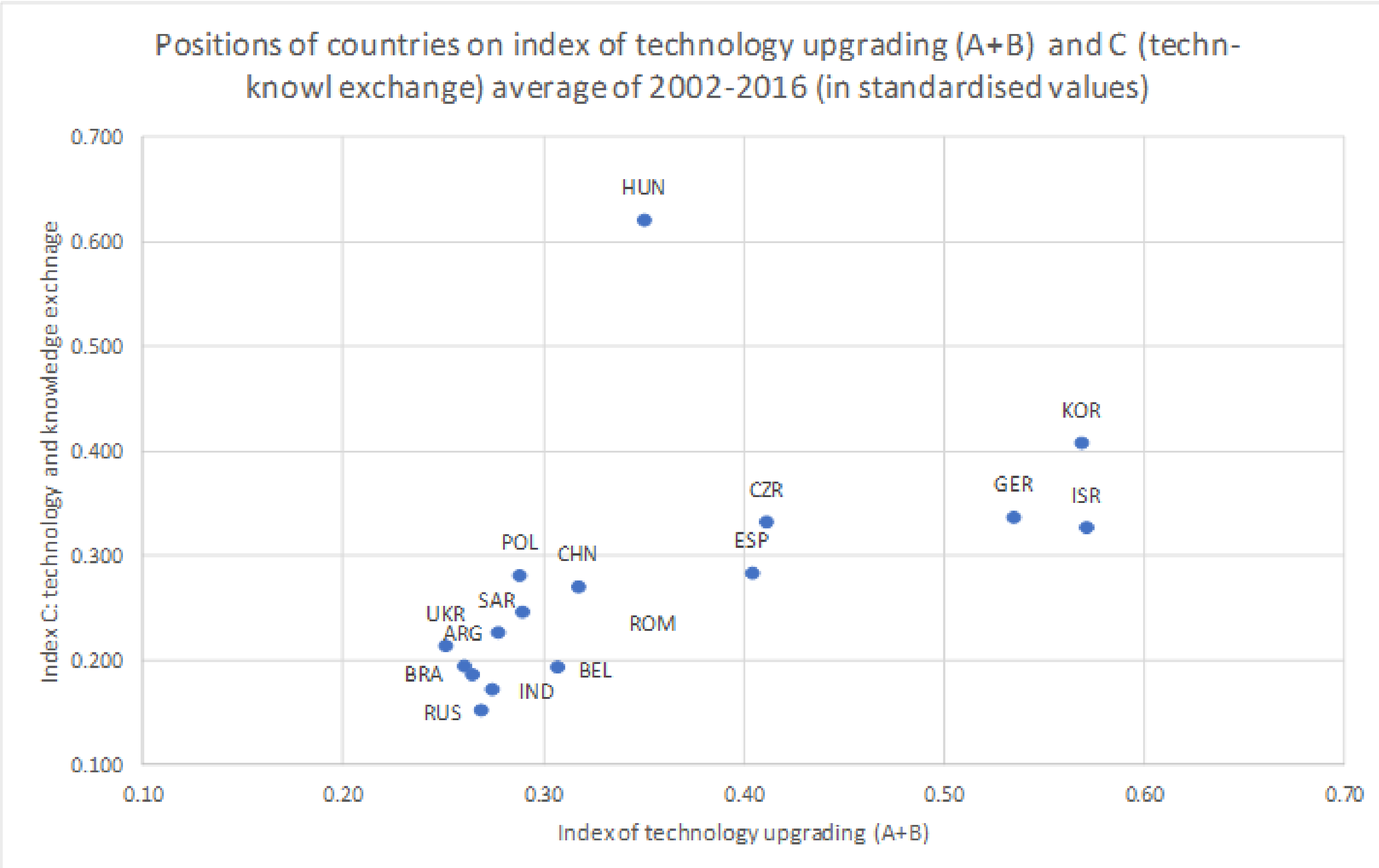


Technology Upgrading in Emerging Economies: A New Approach to its Measurement, Results and Relationship with the Mainstream Measures [1]

The chapter for the book "*Technology Upgrading and Economic Catch-Up*", edited by Jeong-Dong Lee, Keun Lee, Slavo Radosevic, Dirk Meissner, Nicholas S. Vonortas to be published by Oxford University Press

Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*

Figure 3: Index of Technology Upgrading and Knowledge Exchange



Technology Upgrading in Emerging Economies: A New Approach to its Measurement, Results and Relationship with the Mainstream Measures [1]

The chapter for the book "*Technology Upgrading and Economic Catch-Up*", edited by Jeong-Dong Lee, Keun Lee, Slavo Radosevic, Dirk Meissner, Nicholas S. Vonortas to be published by Oxford University Press

Randolph Luca Bruno*, Kirill Osaulenko* and Slavo Radosevic*