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R&D, Innovation and Economic Growth: Can we make the relationship sustainable?

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Agenda

- Global Trends in R&D
- Innovation and Economic Growth
- Should governments invest in R&D and innovation?
- Making Innovation and Economic Growth Sustainable

Trends in R&D

Trends in Aggregate R &D Expenditure

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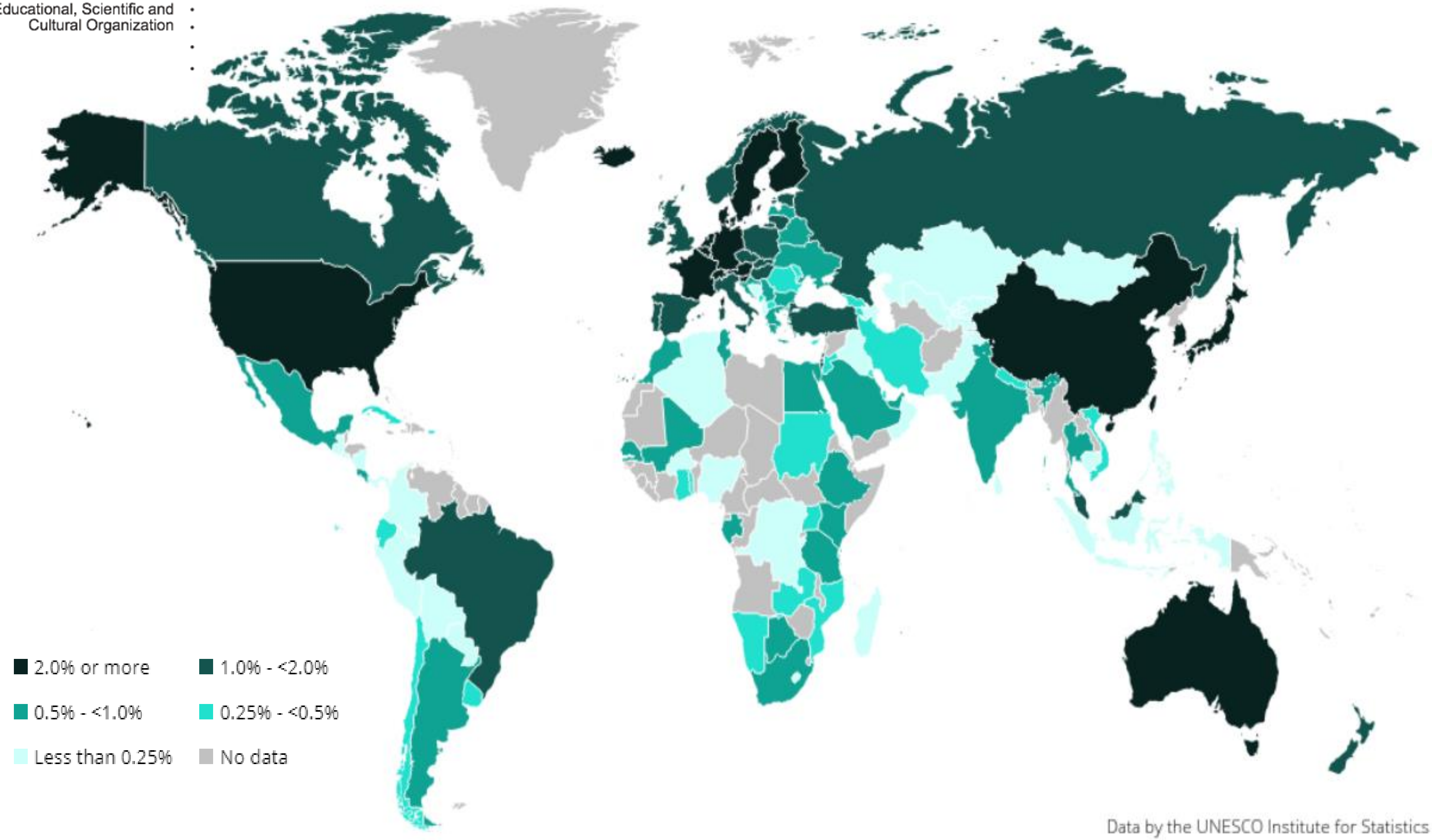
R&D expenditure as a % of GDP, 20



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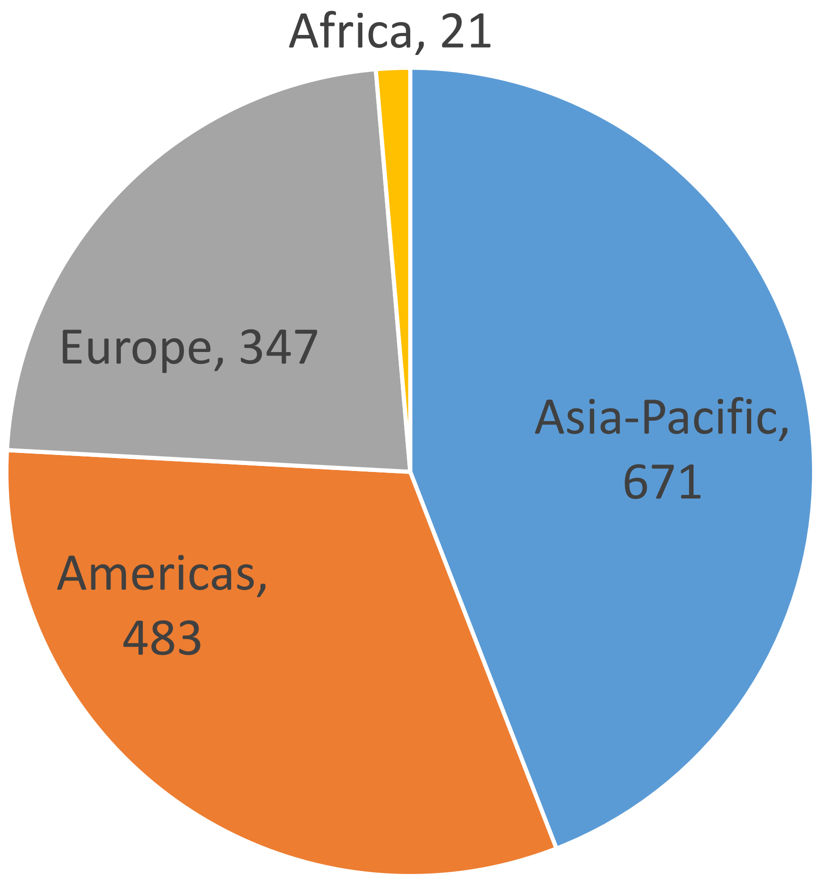
Source: UIS, June 2017

Gross domestic expenditure on R&D



Figures are in constant 2005 billion Purchasing Power Parity Dollars (PPP$).

Source: UIS, December 2016

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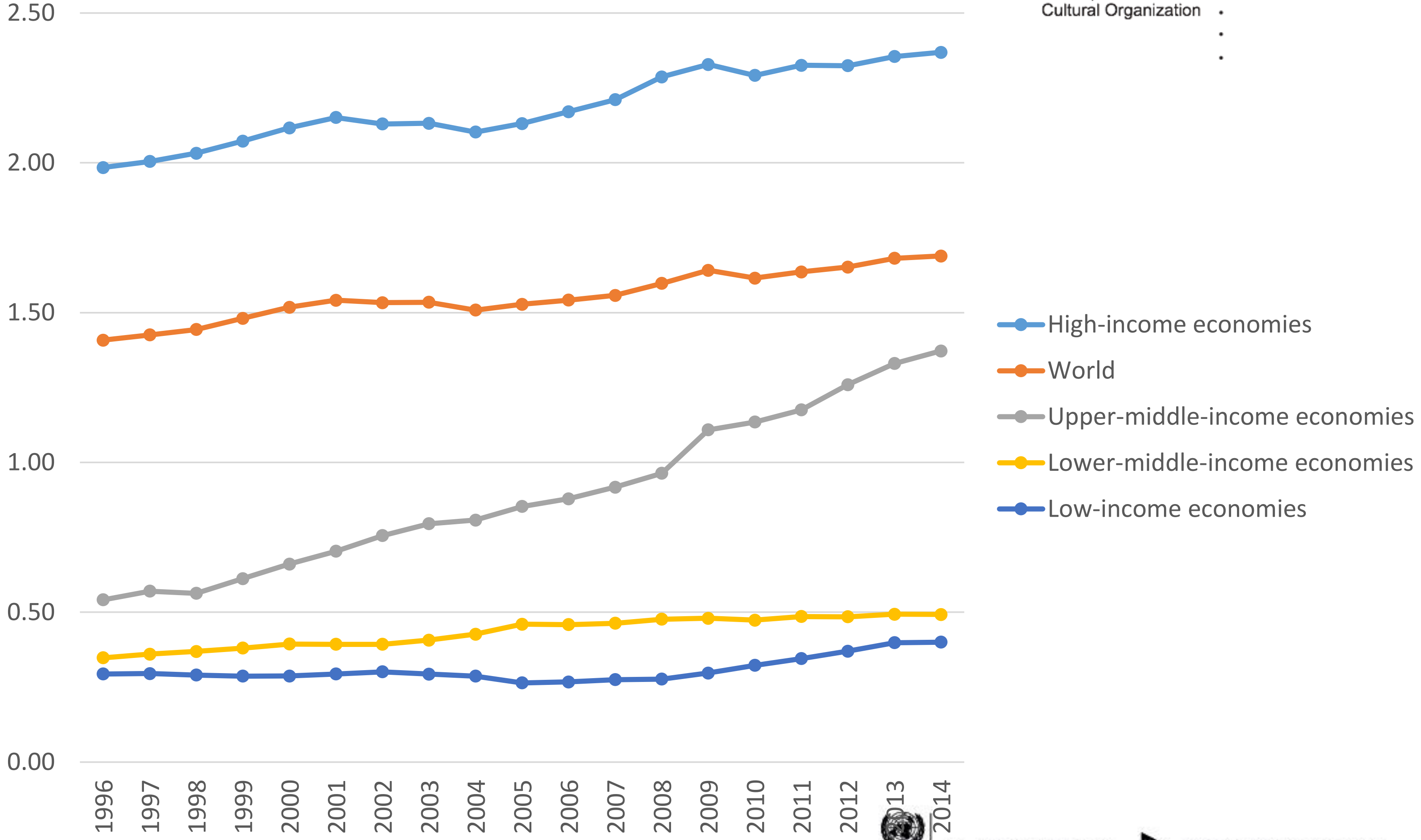
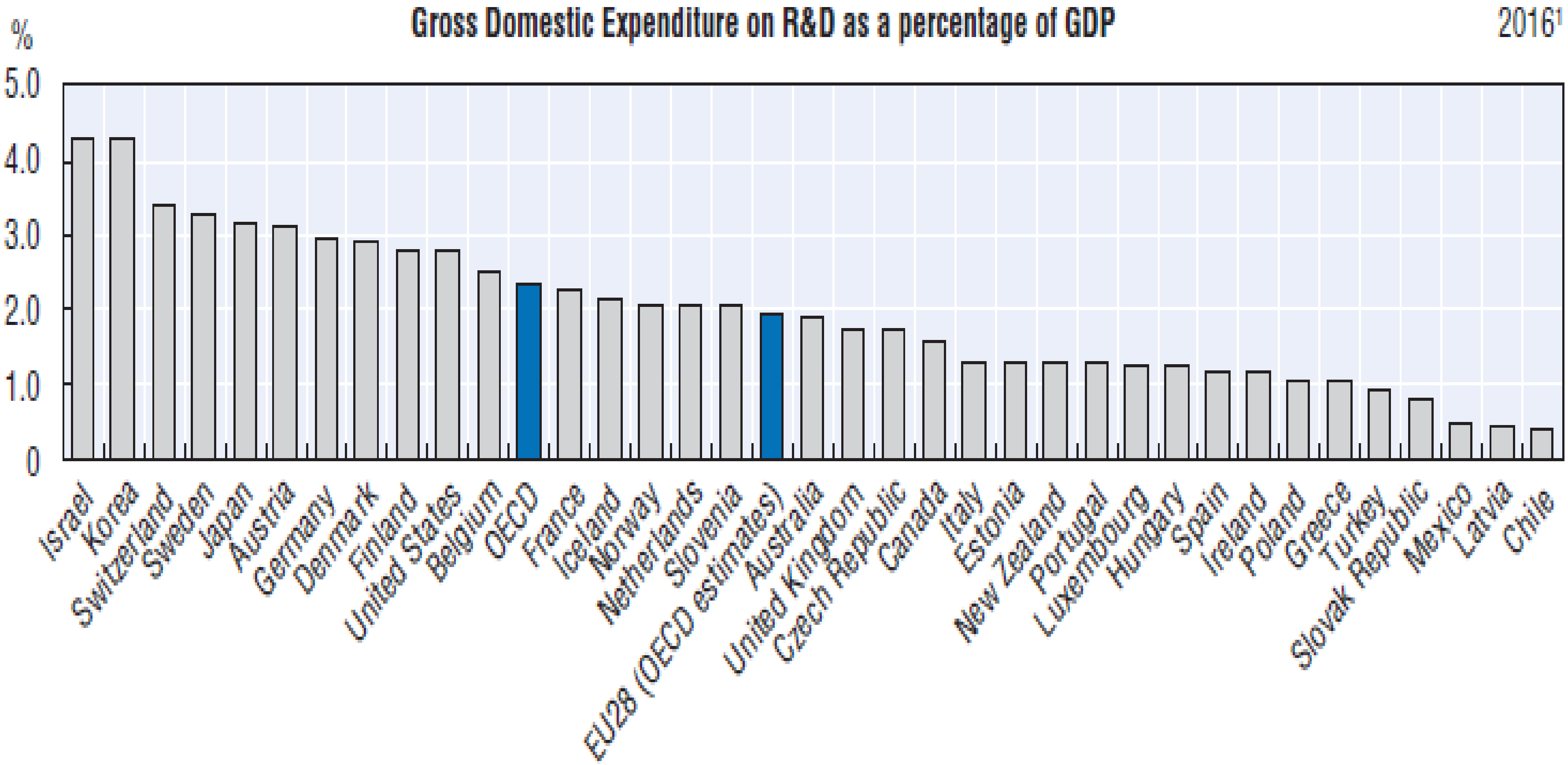
R&D intensity by region

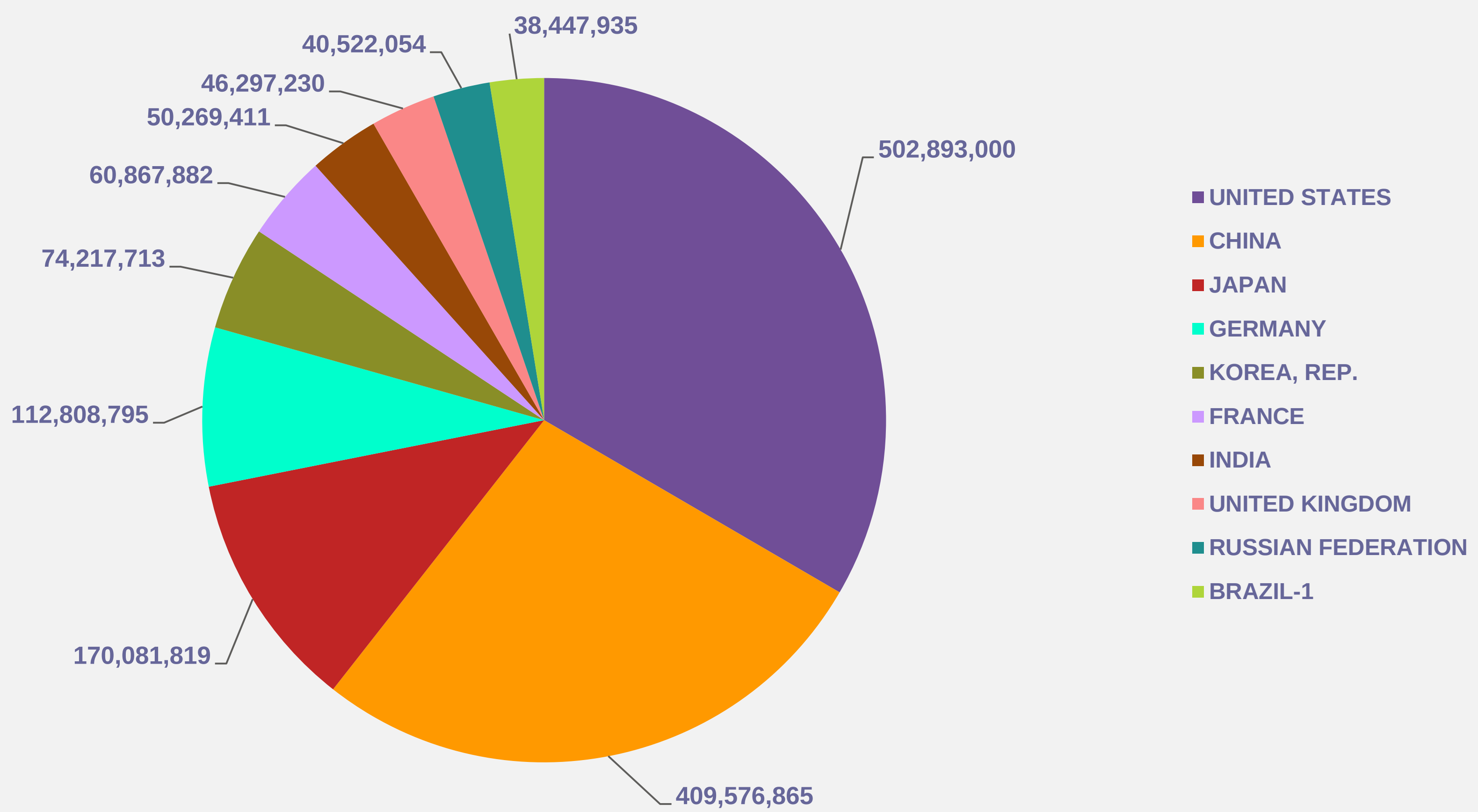


Source: UIS, December 2016

Gross Domestic Expenditure on R&D



Which are the top countries in 2015?
R&D expenditure ('000s PPP$)



Source: UIS, June 2017

Sectoral R&D Trends

	Agriculture			Manufacturing			Mining, construction and utilities			Services		
	Billion PPP$	Shares of total R&D expenditure (percent)	Sectoral R&D intensity (percent)	Billion PPP$	Shares of total R&D expenditure (percent)	Sectoral R&D intensity (percent)	Billion PPP$	Shares of total R&D expenditure (percent)	Sectoral R&D intensity (percent)	Billion PPP$	Shares of total R&D expenditure (percent)	Sectoral R&D intensity (percent)
Low- and middle-income countries												
China	0.48	0.26	0.04	162.47	86.56	3.78	12.69	6.76	0.64	12.05	6.42	0.21
Poland	0.01	0.77	0.06	0.95	49.15	0.70	0.05	2.76	0.05	0.91	47.32	0.19
Turkey	0.01	0.27	0.01	2.59	53.34	1.23	0.07	1.36	0.06	2.19	45.04	0.30
High-income countries												
Australia	0.13	1.04	0.56	2.98	24.57	4.29	3.51	28.94	1.85	5.51	45.46	0.86
Austria	0.00	0.03	0.04	4.34	63.69	7.02	0.09	1.29	0.27	2.38	34.98	1.04
Belgium	0.03	0.46	1.09	4.21	62.93	7.13	0.14	2.14	0.40	2.30	34.48	0.75
Canada*	0.11	0.83	0.55	6.03	46.62	4.41	1.05	8.11	0.48	5.75	44.44	0.63
Czech Republic	0.01	0.33	0.13	1.46	56.23	2.19	0.04	1.50	0.11	1.09	41.94	0.66
Denmark	0.01	0.14	0.21	2.48	51.94	9.34	0.05	0.99	0.21	2.24	46.92	1.43
Finland	0.01	0.10	0.11	4.27	76.83	12.06	0.12	2.17	0.64	1.16	20.90	0.90
France	0.18	0.52	0.44	17.00	49.75	6.82	0.81	2.37	0.44	16.18	47.36	0.94
Germany	0.16	0.25	0.65	55.77	85.62	7.93	0.35	0.53	0.15	8.86	13.60	0.42
Italy	0.00	0.03	0.01	10.36	73.60	3.43	0.15	1.07	0.09	3.56	25.30	0.25
Japan	0.03	0.02	0.05	100.35	87.87	12.35	1.56	1.37	0.47	12.26	10.74	0.39
Korea, Rep. of	0.04	0.09	0.12	39.11	87.54	8.81	1.57	3.51	1.58	3.96	8.85	0.47
Norway	0.08	3.14	1.98	0.98	37.07	4.66	0.35	13.08	0.37	1.23	46.70	0.78
Portugal	0.00	0.24	0.09	0.70	35.48	2.16	0.05	2.42	0.21	1.21	61.86	0.64
Slovenia	0.00	0.08	0.07	0.76	72.08	7.07	0.02	1.69	0.35	0.27	26.15	0.81
Spain	0.14	1.32	0.40	5.85	55.70	3.10	0.68	6.44	0.42	3.84	36.54	0.38
Sweden	0.02	0.25	0.38	6.59	71.86	9.91	0.05	0.51	0.13	2.51	27.38	0.98
United Kingdom	0.02	0.07	0.13	9.18	36.90	4.39	0.35	1.40	0.16	15.33	61.63	0.95
United States	—	—	—	201.36	—	10.56	3.79	—	0.30	88.95	—	0.73

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Trends in R&D Personnel

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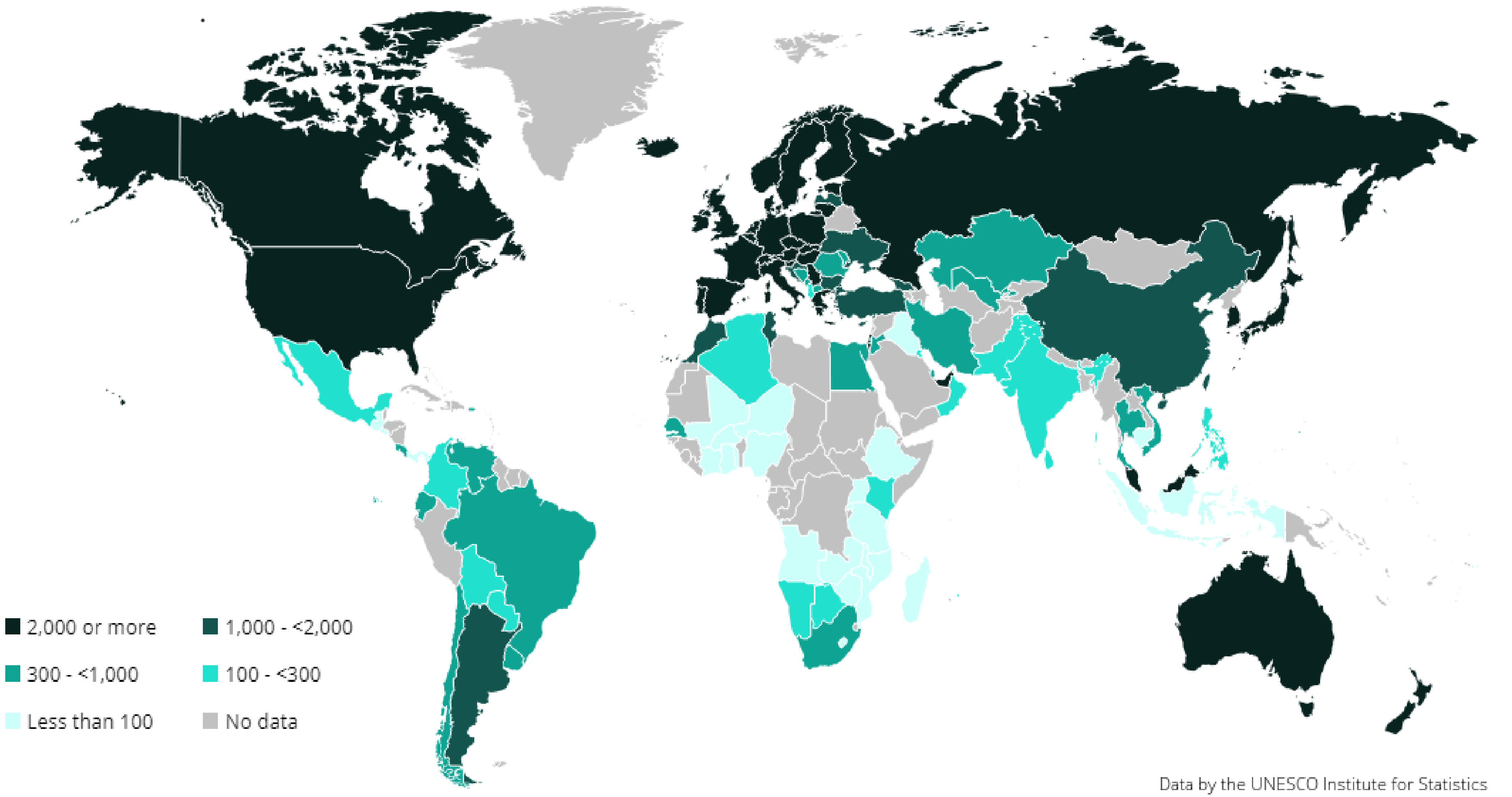
Researchers (FTE) per million pop. 2015



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Source: UIS, June 2017

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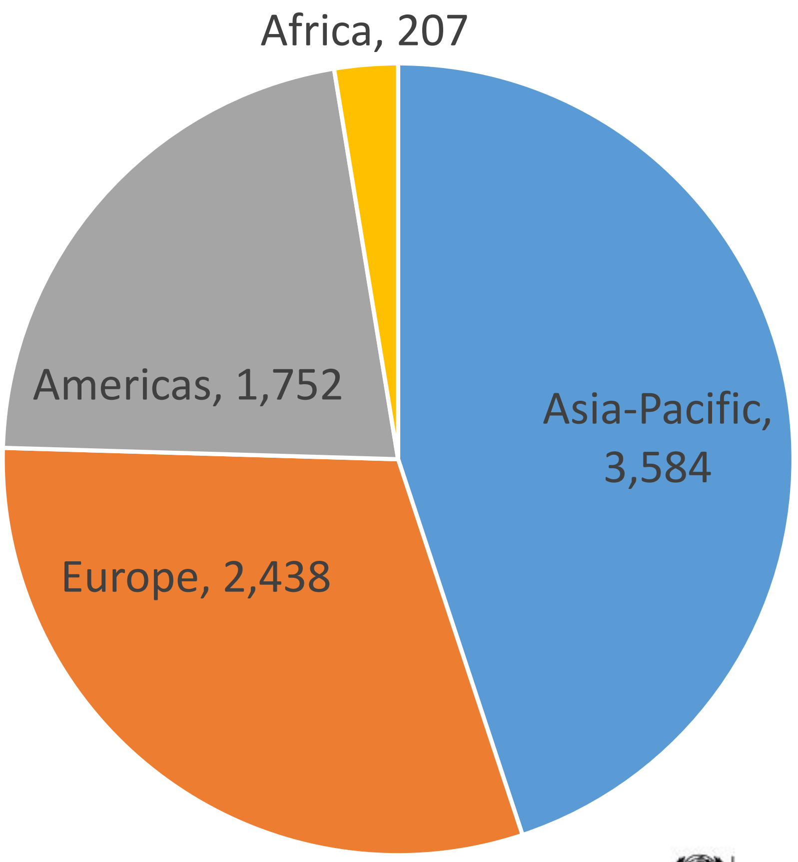
How many researchers are there?
Number of researchers (FTE) ('000s), 2014



Source: UIS, December 2016

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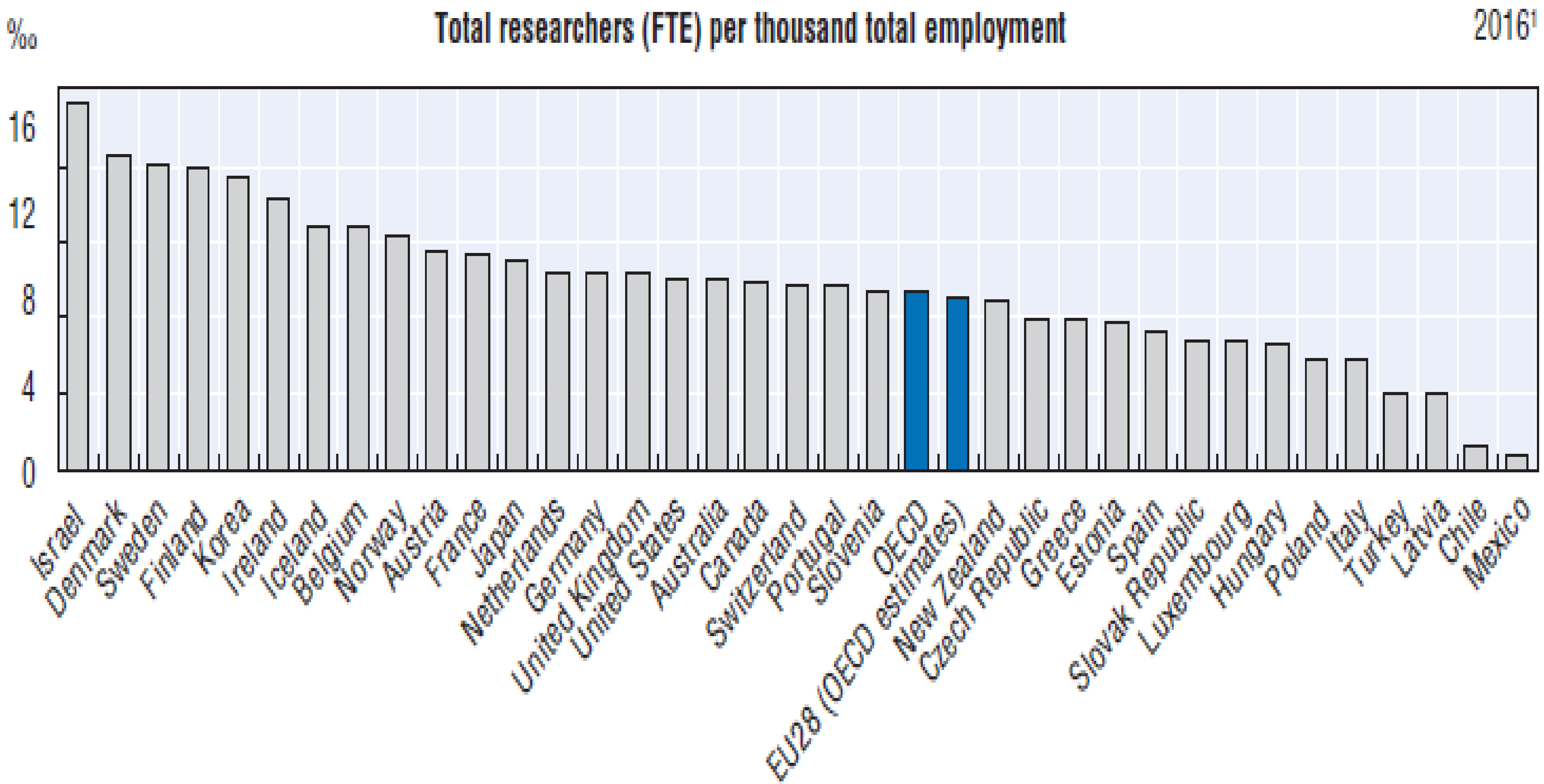
Total Researchers



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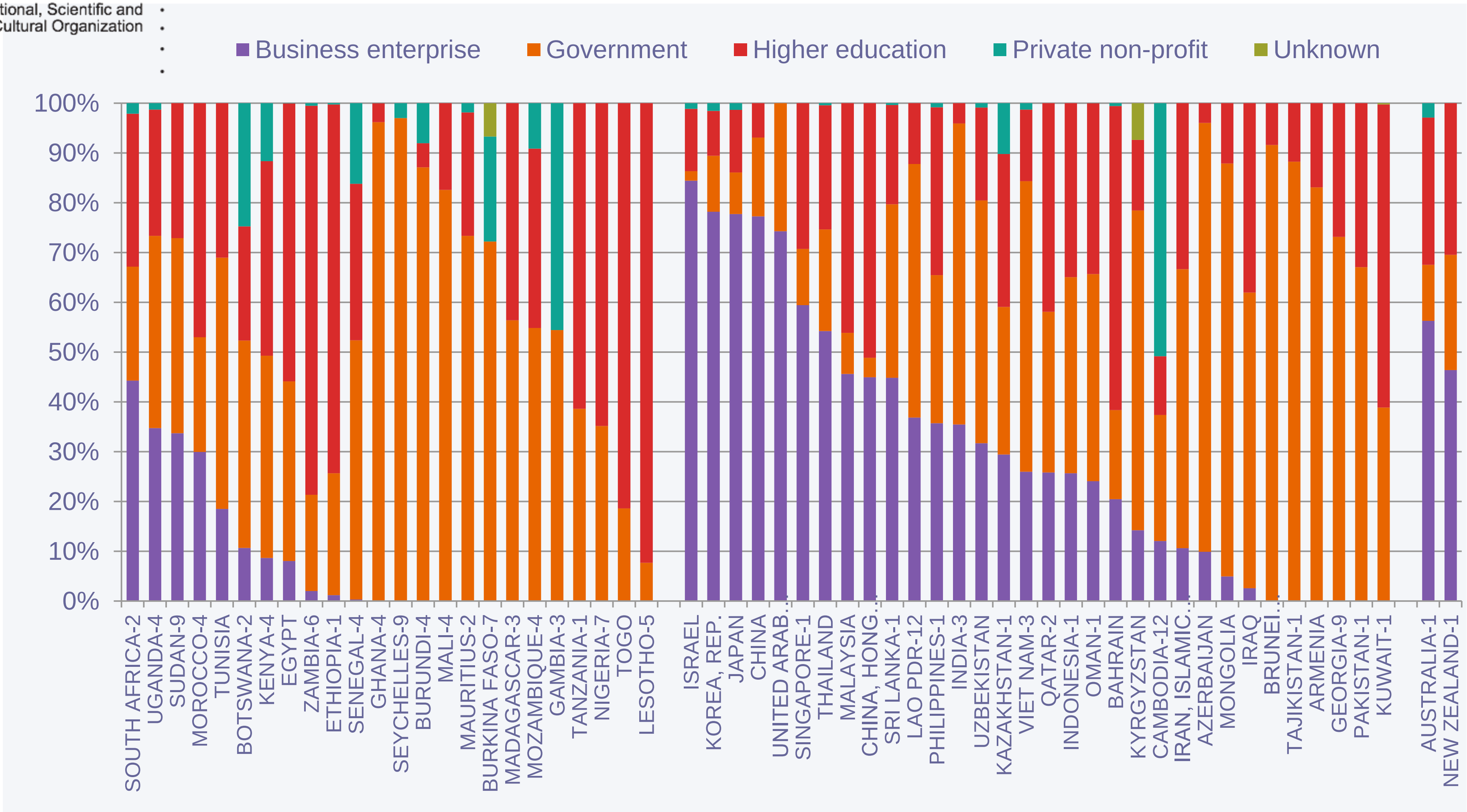
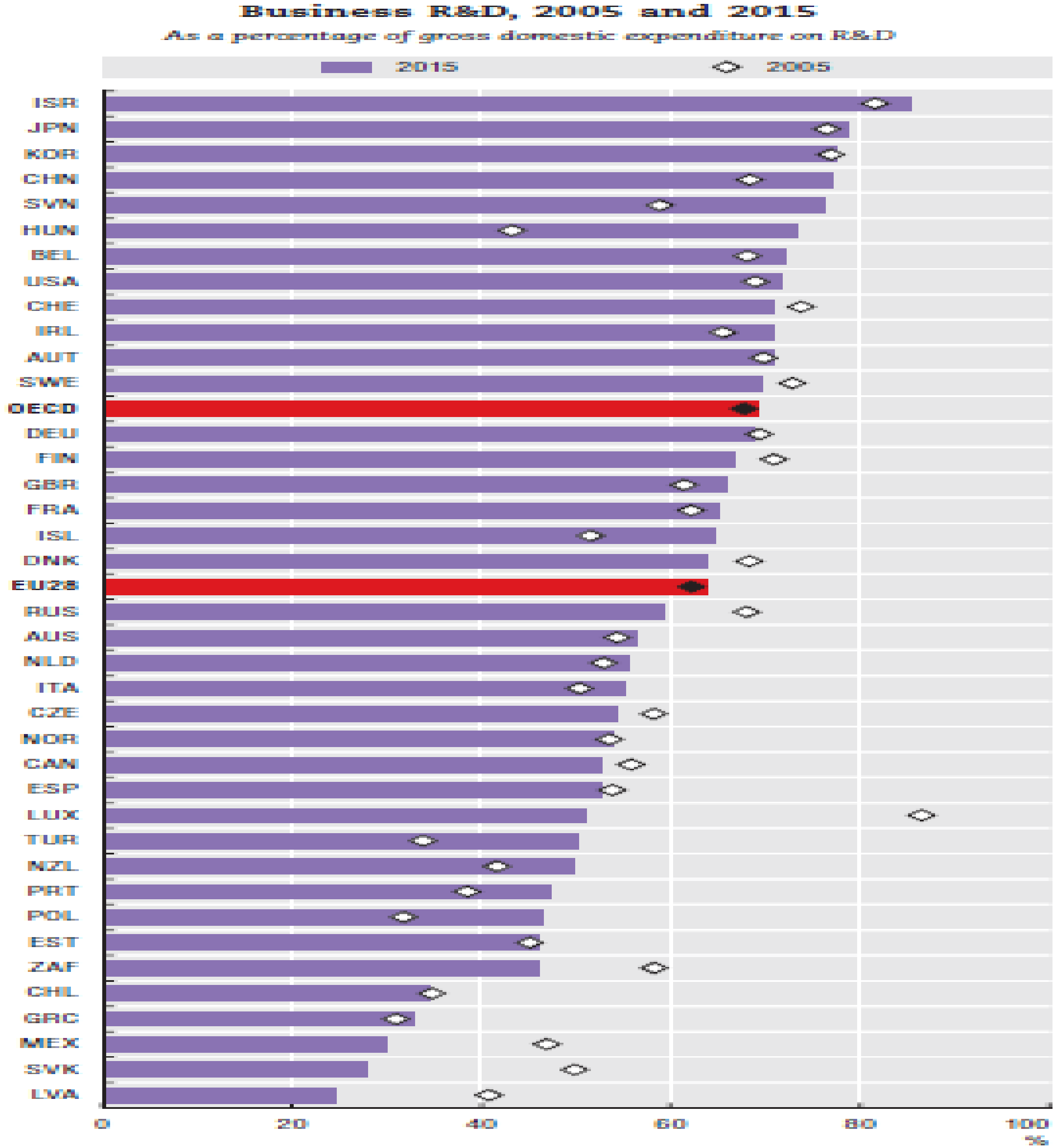
Trends in Private R&D

GERD by sector of performance, 2014 or latest available year



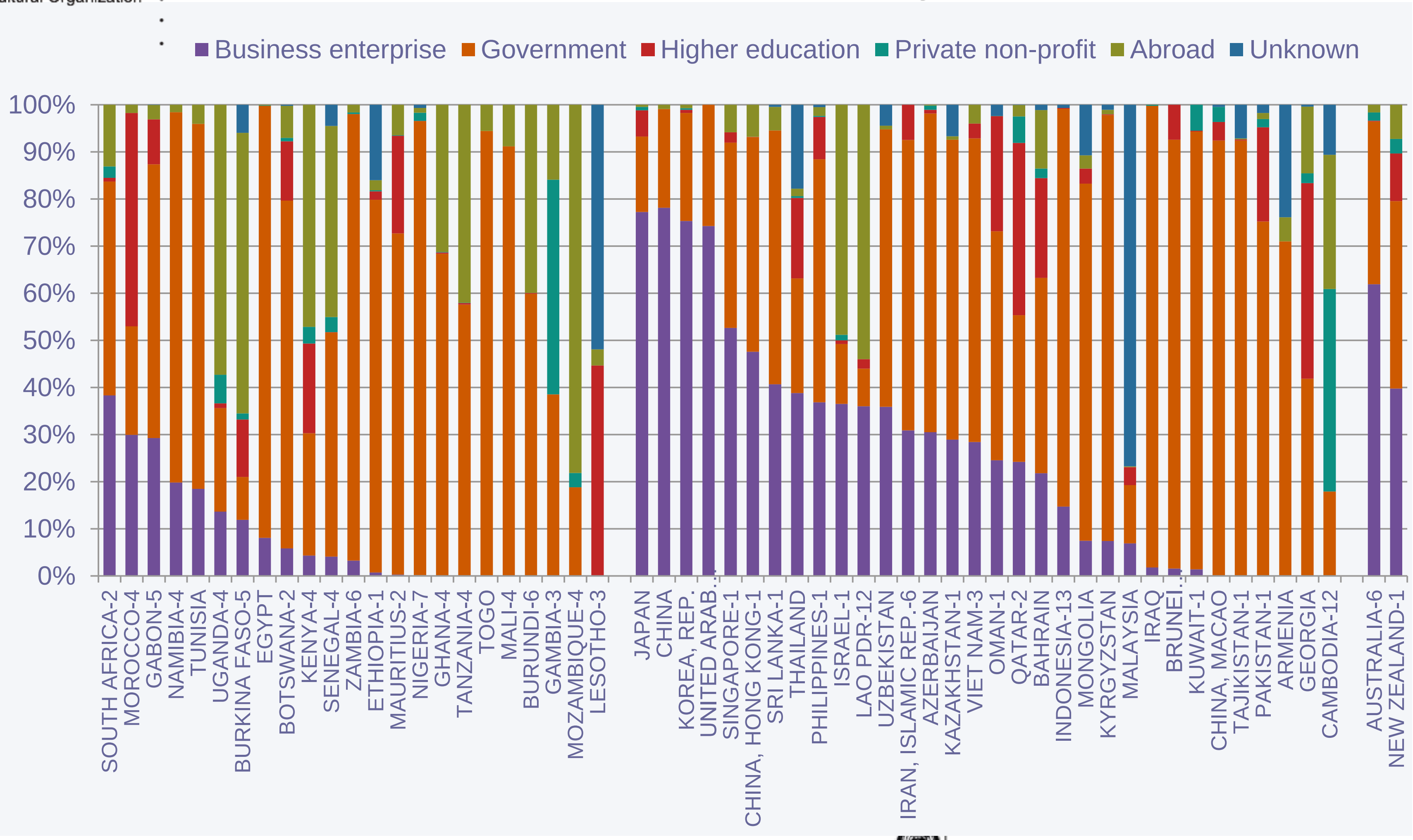
Source: UIS, October 2016

Note: -1 = 2013, -2 = 2012, -3 = 2011, -4 = 2010, -5 = 2009, -6 = 2008, -7 = 2007, -8 = 2006, -9 = 2005, -10 = 2004, -12 = 2002..



Source: OECD, Main Science and Technology Indicators Database, http://oe.cd/msti, July 2017. StatLink contains more data. See chapter notes.

GERD by source of funds, 2014 or latest available year

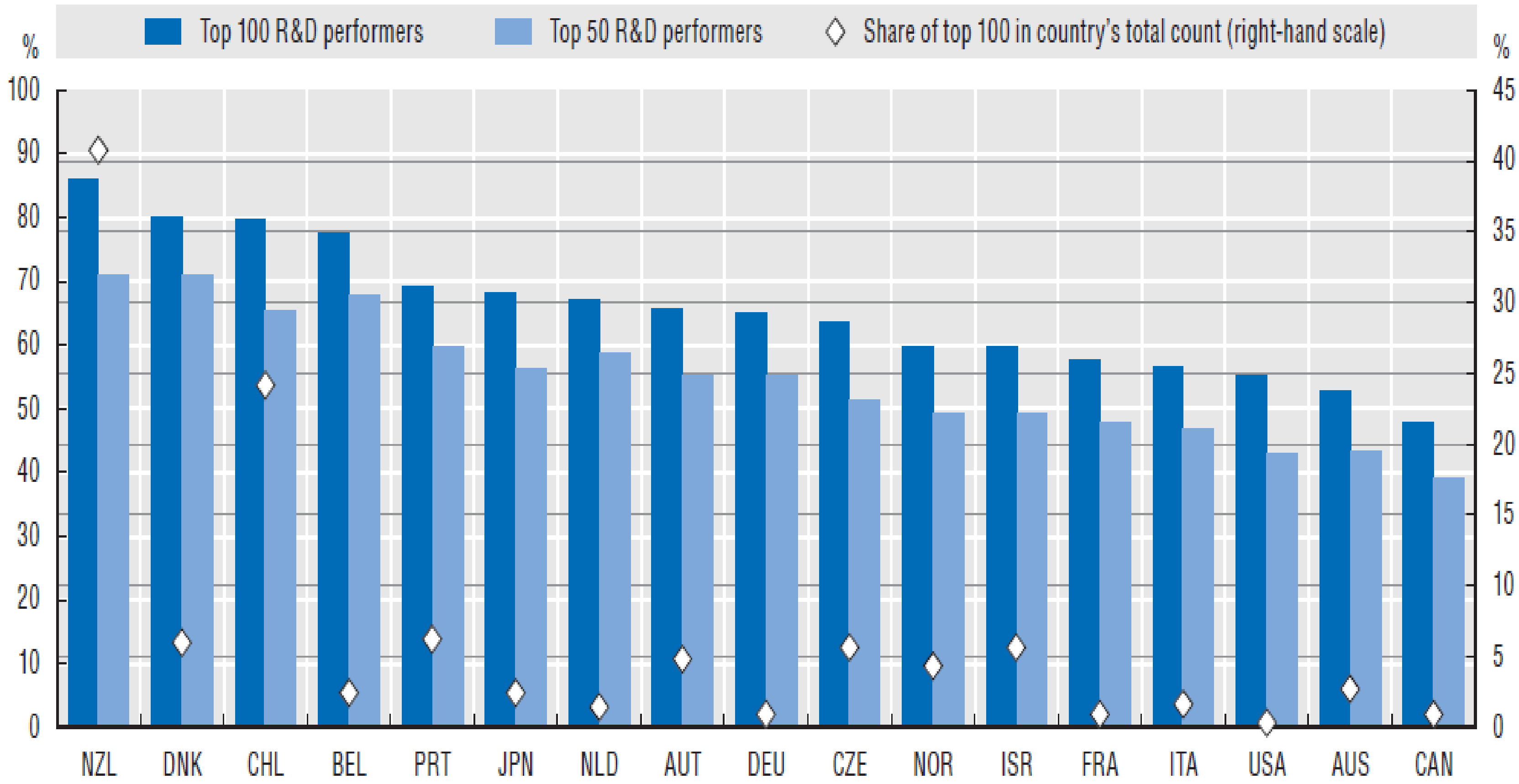


Note: -1 = 2013, -2 = 2012, -3 = 2011, -4 = 2010, -5 = 2009, -6 = 2008, -7 = 2007, -10 = 2004, -12 = 2002, -13 = 2001.

Source: UIS, October 2016

Concentration of business R&D: top 50 and top 100 performers, 2014

As a percentage of domestic business R&D expenditure and of total count of performers



Source: OECD, based on preliminary results from the OECD microBeRD project, *http://oe.cd/microberd*, July 2017. See chapter notes.

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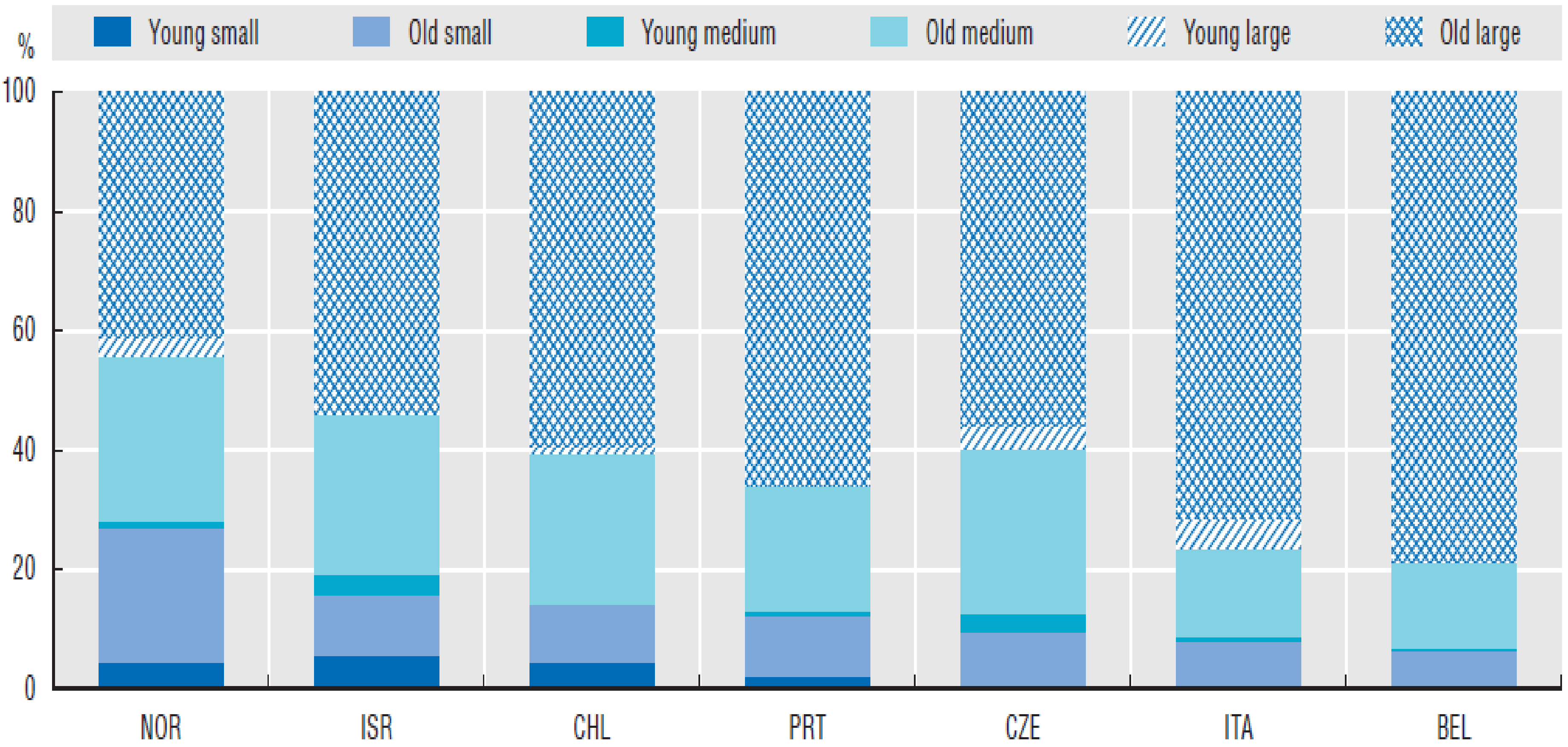
Business R&D performance by size and age, 2014

As a percentage of domestic business R&D expenditure



Source: OECD, based on preliminary results from the OECD microBeRD project, *http://oe.cd/microberd*, July 2017. See chapter notes.

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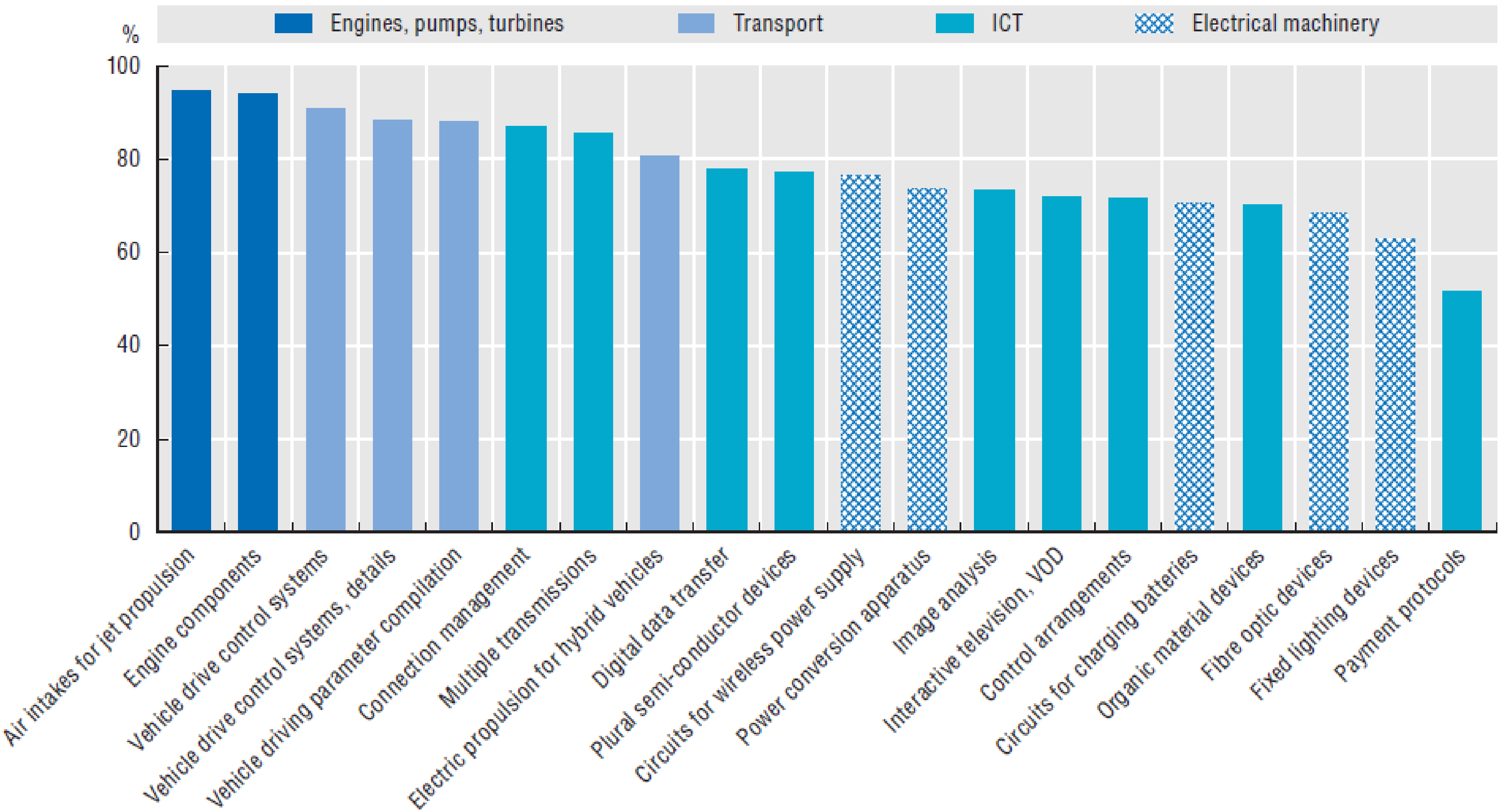
Top 20 emerging technologies developed by top R&D companies, 2012-14

Share of patents owned by top 2000 R&D companies in total IP5 patent families in the field, percentages



Source: OECD calculations based on JRC-OECD, COR&DIP© Database v.1. and OECD, STI Micro-data Lab: Intellectual Property Database, *http://oe.cd/ipstats*, July 2017. See chapter notes.

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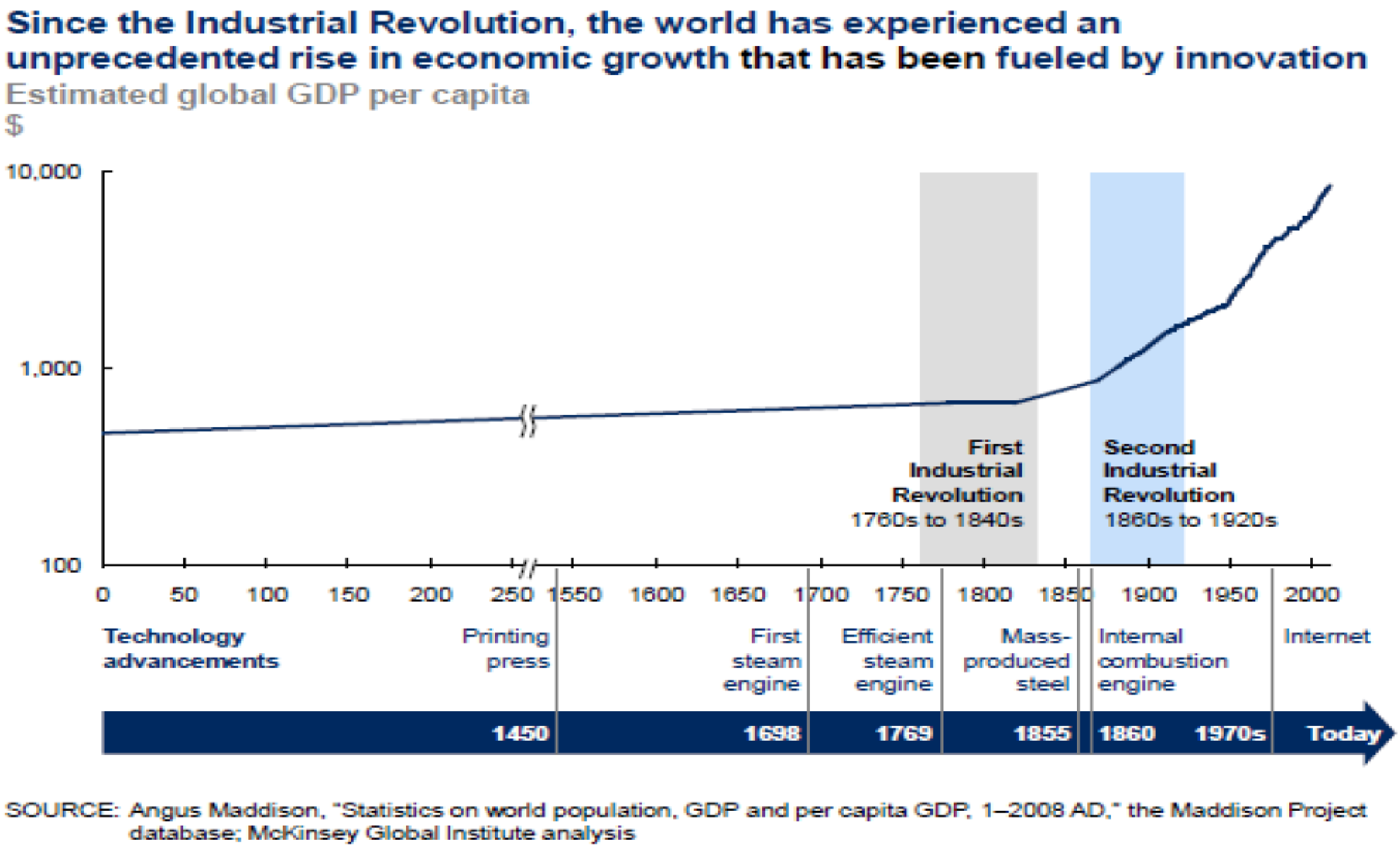
Innovation and Economic Growth

The economic determinants of economic growth

- The accumulation of physical capital
- Human capital
- Research and development
- Macroeconomic conditions
- Financial
- International trade
- Government policies and institutional setting

Approaches exploring the link between technology and innovation an growth: historical

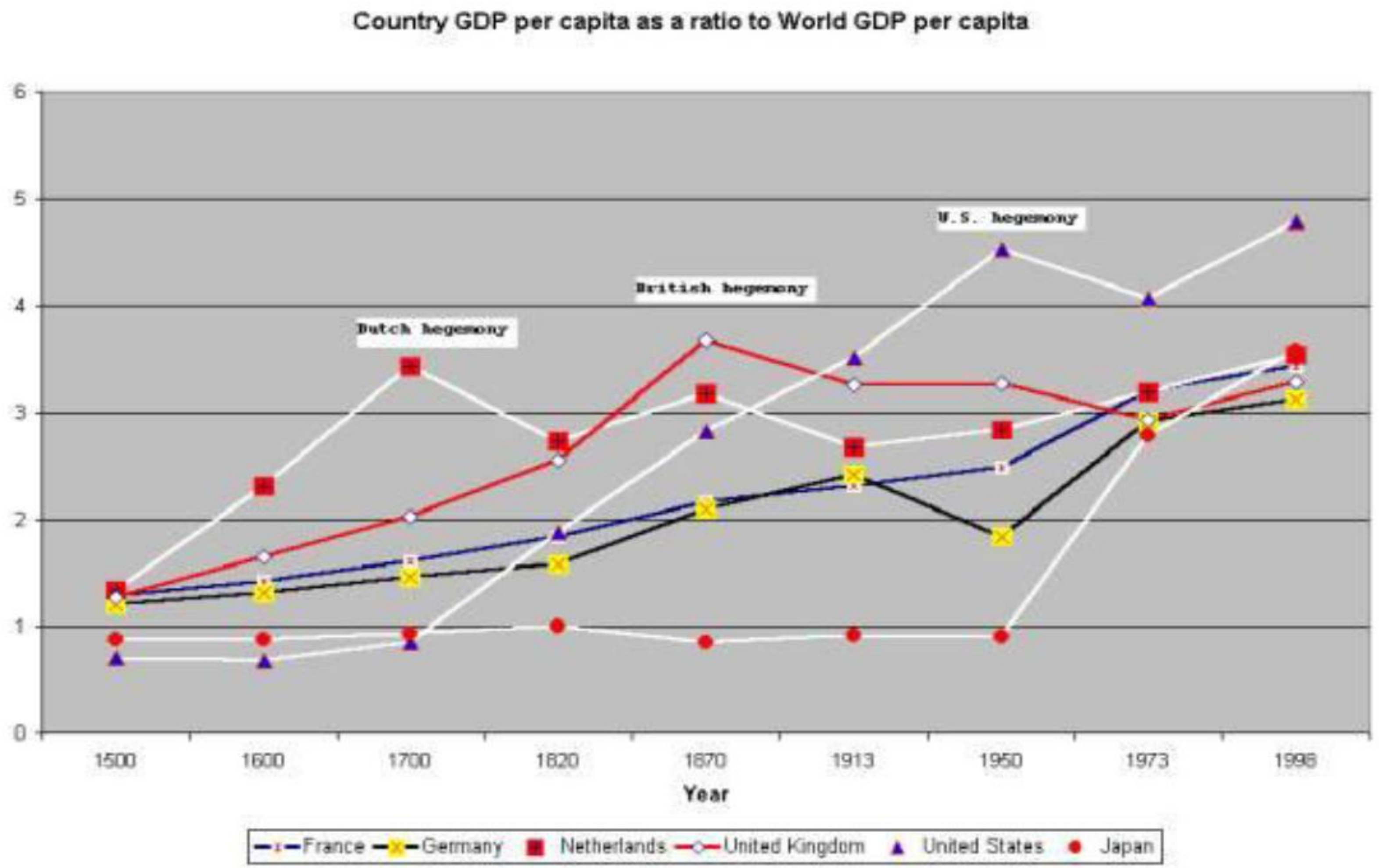


Approaches exploring the link between technology and innovation an growth: historical

No.	GPT	Date[2]	Classification
1	Domestication of plants	9000–8000 BC	Pr
2	Domestication of animals	8500–7500 BC[3]	Pr
3	Smelting of ore	8000–7000 BC	Pr
4	Wheel	4000–3000 BC[4]	P
5	Writing	3400–3200 BC	Pr
6	Bronze	2800 BC	P
7	Iron	1200 BC	P
8	Waterwheel	Early medieval period	P
9	Three-masted sailing ship	15th century	P
10	Printing	16th century	Pr
11	Steam engine	Late 18th to early 19th century	P
12	Factory system	Late 18th to early 19th century	O
13	Railway	Mid 19th century	P
14	Iron steamship	Mid 19th century	P
15	Internal combustion engine	Late 19th century	P
16	Electricity	Late 19th century	P
17	Motor vehicle	20th century	P
18	Airplane	20th century	P
19	Mass production, continuous process, factory[5]	20th century	O
20	Computer	20th century	P
21	Lean production	20th century	O
22	Internet	20th century	P
23	Biotechnology	20th century	Pr
24	Nanotechnology[6]	Sometime in the 21st century	Pr

Note: P, product; Pr, process; O, organizational.

Approaches exploring the link between technology and innovation an growth: historical



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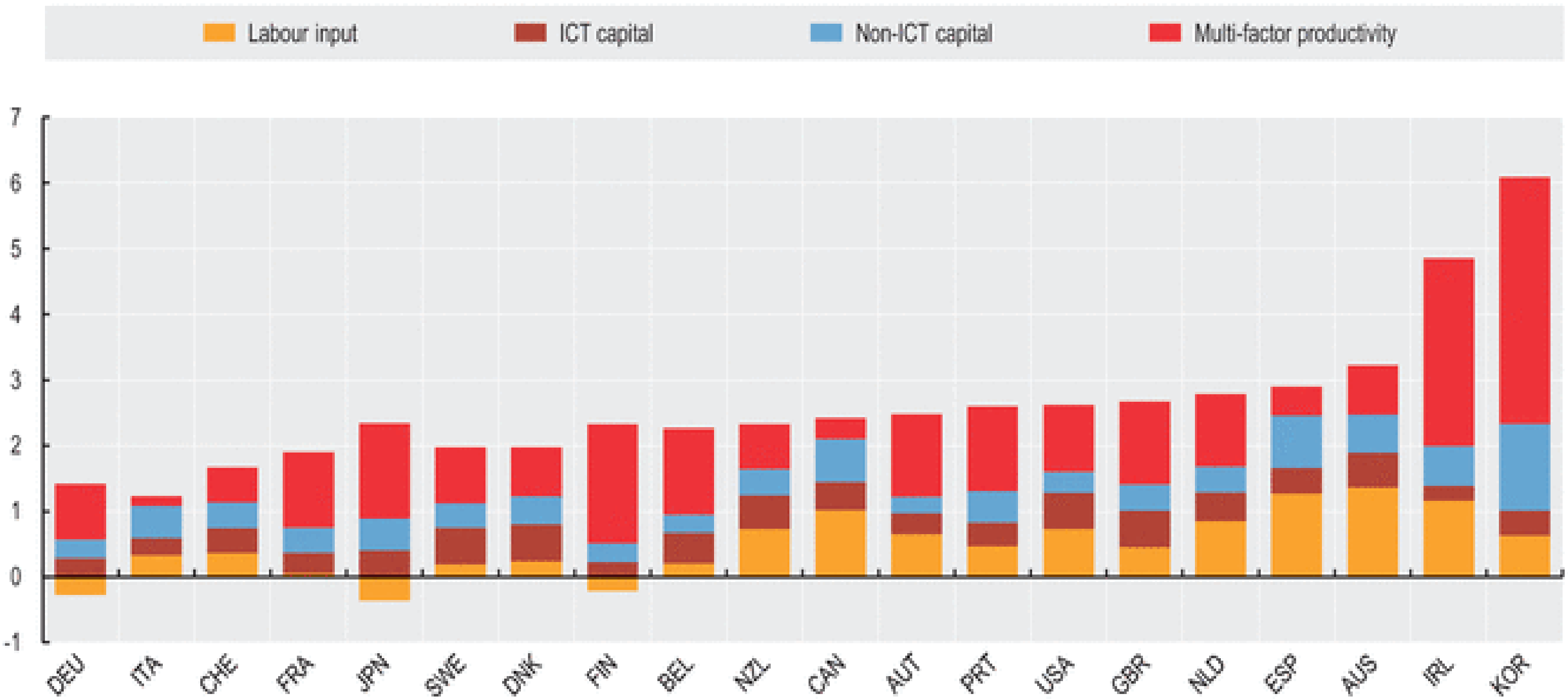
Approaches exploring the link between technology and innovation an growth: neoclassical

- The Solow Model: perfect competition and information, positive and decreasing marginal products, absence of scale economies, declining marginal productivity of capital, freely accessible knowledge globally for everybody free of charge
- Growth arises from the accumulation of capital, which eventually reaches a limit although this can be postponed to the long run through the adoption of technology
- In the long run all countries converge, since everyone has access to technology
- Technology is determined outside the growth process (‘exogeneous’)
- Technology is estimated through a procedure called ‘growth accounting’, which suggested that the contribution made by capital and labour to economic growth in the US was minimal but rather the contribution from a residual term called total factor productivity, which represented technology was rather large

Contributions to GDP growth

Average annual growth in percentage, 2000-2011 (or closest comparable year)



Source: *OECD Factbook 2011-2012*

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Approaches exploring the link between technology and innovation an growth: capabilities

- Starting point is the idea of *convergence* as a result of the diffusion of *technological knowledge* from rich to poor countries
- The efficiency with which assimilating knowledge from abroad takes place depends on <u>social capability</u> and on <u>technological congruence</u> (Abramovitz)
  - Social capability captures broad institutions (politics), human capital (education), finance, infrastructure, etc.
  - Technological congruence is whether knowledge from abroad is relevant for the local production structure (microchips for an agricultural economy?)
- If social capability and technological congruence are initially low, it is hard to grow by assimilating foreign knowledge
- Social capability will grow when development takes off

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Approaches exploring the link between technology and innovation an growth: capabilities

- Technological congruence will grow when the production system is modernized
- This mutual-reinforcing process can easily get stuck in a low development trap
- This is why we observe divergence and falling behind at the global scale
- How can countries break out of the trap?
  - Countries can escape the trap by an active policy of learning, which enables them to build absorptive capacity and technological capabilities
  - Targeting of specific sectors and changing these targets along the way
  - Gradual upgrading of firms' capabilities and increasing the complexity of goods produced and traded
  - Building local innovation systems

Examples of capabilities

Dimension	Measure
Science, research and innovation	Scientific publications, patents, R&D (total/business), innovation counts
Openness	Openness to trade, foreign direct investment, research cooper-ation/alliances with foreign partners, technology licensing, im-migration
Production qual-ity/standards	International (ISO) standards, total quality management (TQM), lean production, just-in-time
ICT infrastructure	Telecommunications, internet, computers
Finance	Access to bank credit, stock-market, venture capital
Skills	Primary, secondary and tertiary education, managerial and tech-nical skills
Quality of governance	Corruption, law and order, independence of courts, property rights, business friendly regulation
Social values	Civic activities, trust, tolerance, religious ethics, attitudes to-wards technology and science

Examples of capabilities

Table 1. Illustrative matrix of technological capabilities

DEGREE OF COMPLEXITY		FUNCTIONAL: INVESTMENT				PRODUCTION	
		PRE INVESTMENT	PROJECT EXECUTION	PROCESS ENGINEERING	PRODUCT ENGINEERING	INDUSTRIAL ENGINEERING	LINKAGES WITHIN ECONOMY
BASIC	SIMPLE, ROUTINE (Experience based)	Prefeasibility and feasibility studies, Site selection, scheduling of investment	Civil construction, ancillary services, equipment erection commissioning	Debugging, balancing quality control preventive maintenance, assimilation of process technology	Assimilation of product design, minor adaptation to market needs	Work flow, scheduling, time-motion studies. Inventory control	Local procurement of goods and services, information exchange with suppliers
INTERMED	ADAPTIVE DIPLICATIVE	Search for technology source. Negotiation of contracts. Bargaining suitable terms. Info. systems	Equipment procurement, detailed engineering, training and recruitment of skilled personnel	Equipment stretching, process adaptation and cost saving, licensing new technology	Product quality improvement, licensing and Assimilating new imported product technology	Monitoring productivity, improved coordination	Technology transfer of local supplies, coordinated design, S&T links
ADVANCED	INNOVATIVE RISKY (Research based)		Basic process design. Equipment design and supply	In-house process innovation, basic research	In-house product innovation, basic research		Turnkey capability, cooperative R&D, licensing own Technology to others.

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Approaches exploring the link between technology and innovation an growth: knowledge

- Associated with New Growth Theory perspectives (Romer)
- Development gaps across countries are the result of differences in endogenous knowledge accumulation
- Knowledge exhibits increasing returns so there is no limit to its accumulation. As a result:
  - Opportunities for Growth May be Almost Limitless and depend on the capacity to generate ideas
  - Countries must invest in knowledge generation
  - Knowledge generation needs to be protected through strong IPRs
- Countries may catch up through strong international trade and investment ties that may provide them access to knowledge

Approaches exploring the link between technology and innovation an growth: firms

- Focuses on the behavior across firms on parameters such as technological intensity, multiplier effects, size, survival rates, skill availability and extent of product and process innovation
- Generally rely on firm data obtained from innovation surveys in Europe and some developing countries or from the Productivity and Investment Climate surveys organized by the World Bank
- Types of conclusions reached by this literature:
  - German high-tech firms are likely to generate more new products than their low tech counterparts
  - Innovation is a quite frequent phenomenon among firms in developing countries although these tend to be new to the firm
  - In developed countries large firms are more innovative than small firms and the age of the firm doesn't affect the degree of innovativeness
  - Firms that use external sources of knowledge are more innovative than those that use less external knowledge

Innovation survey results

Table 3: Innovation surveys in catching-up economies

	GDP per capita (PPP)	Response rate	Number of respondents	Reference period	% of firms with new or significantly improved: Product	Process
Slovenia	18,405	88%	2,960	02-04	20	22
Korea[a)]	18,271	61%	..	02-04	36	23
Taiwan	18,247	34%	3,356	98-00	28	33
Czech Rep.	17,634	74%	6,188	03-05	27	30
Hungary	14,836	77%	3,950	02-04	14	13
Slovakia	12,803	73%	2,195	02-04	15	17
Estonia	11,892	79%	2,201	02-04	37	33
Croatia	11,639	77%	3,094	04-06	17	24
Poland	11,608	87%	..	02-04	15	19
Argentina[a)]	11,421	76%	1,627	02-04	39	37
Lithuania	11,042	94%	1,639	02-04	17	20
Latvia	10,101	..	2,990	02-04	9	10
South Africa	9,290	37%	979	02-04	42	35
Chile[a)]	9,103	15%	706	99-01	43	40
Russia	9,101	..	..	04	Less than 10%	
Mexico[a)]	9,038	69%	1,515	99-00	27	24
Malaysia[a)]	8,496	19%	749	00-01	32	27
Uruguay[a)]	7,981	98%	814	01-03	23	26
Turkey	7,460	..	..	04-06	22	23
Bulgaria	7,212	80%	13,710	02-04	14	8
Brazil	7,196	..	10,600	01-03	20	27
Romania	7,193	78%	9,180	02-04	15	18
Thailand	7,091	43%	2,582	03	6	5
Tunisia	6,812	79%	586	02-04	51	49
China[a)]	6,043	82%	31,436	04-06	25	25

Note: [a] Manufacturing firms only.
Source: National statistical offices and other sources.

Table 4: Evidence on innovation from Productivity and Investment Climate Surveys organized by the World Bank

Country	GDP per capita (PPP)	Number of respondents	Reference period	% of firms that innovated: Product	Process
			Questionnaire version 1:		
China	2,496	1,498	98-00	21	30
China	2,787	2,375	99-02	24	33
			Questionnaire version 2:		
Poland	12,488	968	02-04	35	34
Turkey [a]	9,302	1,323	03-04	36	42
Brazil [a]	7,883	1,640	97-02	68	68
Thailand [a]	7,224	1,042	05-06	48	46
Thailand [a]	5,933	1,385	01-02	50	52
Egypt [a]	4,332	977	02-03	15	11
Egypt [a]	4,687	995	04-05	19	..
Morocco [a]	3,107	831	00-02	25	35
India [a]	2,004	2,240	03-04	40	16
Vietnam [a]	1,942	1,149	03-04	44	45
			Questionnaire version 3:		
Mexico [a]	11,142	1,119	03-05	35	34
Ukraine	6,048	848	05-07	57	..
Nigeria [a]	1,736	945	04-06	54	53
Bangladesh [a]	1,071	1,201	04-06	33	45
Turkey	10.870	1,148	05-07	45	..

Note:
[a] Manufacturing firms only
Source: World Bank (2003, 2008).

Should governments invest in R&D and innovation?

Experience and rationale

- Begin shortly after WW2 based on successes achieved during conflict and belief that support to science could have positive effect on economic growth
- Successful experiences of government support to applied research and commercialization of research results in countries like Japan, South Korea convinced many developed and developing countries of the need to provide much broader support to innovation
- Arguments:
  - Market failure. Knowledge cannot be appropriated by creator since to know its value it must be disclosed (paradox of information)
  - Social value of knowledge is higher than its private value
  - Counterargument. Public funding of R&D crowds out the private sector because it reduces the amount of resources for science and development available for them and often allocates monies to large enterprises or based on political or non-economic criteria
- Range of support: indirectly though academic and vocational training, economic infrastructure such as communications or directly by undertaking research projects or financing research centres. Somewhere in the middle: providing an innovation friendly environment
- Support is a political process that requires priorities and hence alignment with national development policies
- Risks: excessive caution, avoiding redundancy, long-term bet and lack of coordination

Making Innovation and Economic Growth Sustainable

Innovation, Economic Growth and Inclusiveness

- Innovation relates to inequality:
  - ➢ through direct impacts on income distribution (innovation favours the highly skilled and risk takers),
  - ➢ as solutions for improving the welfare of lower and middle income groups ("frugal innovation");
  - ➢ through innovations by lower income groups themselves, *i.e.* grassroots activities.
- "Bottom of the pyramid" innovation
- Types of products for lower-income groups
  - health and food as well as agricultural production
  - products aimed at improving basic living conditions and education (*e.g.* mobile telephony
- Demand-side factors for uptake by lower-income groups
  - High sensitivity to price
  - Products must be adequate for the specific user context
  - Information about innovative products is essential
  - Demand has to reflect needs
  - Community involvement and social conditions
- Profitable supply-side business factors for uptake by lower-income groups
  - Pricing and financing strategies
  - Modification of business processes

Box 3.1. Examples of inclusive innovation

Eye care. Through the use of "workflow innovation" India's Aravind Eyecare Hospital has saved over 2 million patients so far from blindness. Cataract surgery, which costs around USD 3 000 in advanced countries, is done for USD 30-300, the price being determined by the capacity to pay. The quality compares with international benchmarks. Aravind Eyecare performs 200 000-300 000 operations a year.

Bici-Lavadora. The Bici-Lavadora (a MIT D-Lab project in the United States), is a portable, pedal-powered washing machine. With an estimated prototype price of USD 127, this innovation stands to increase greatly the productivity of washerwomen and bring some of the benefits of an appliance often taken for granted elsewhere in the world at low cost and without reliance on electricity.

Source: R. Mashelkar and V. Goel (2010), "Inclusive Innovation: More from Less for More", draft.

Table 3.1. Pricing and financing strategies

Pay-as-you go: users can pay in small units for service access instead of high fixed costs

• In India the Byrraju Foundation has provided water purification services at half the price of alternative ways to obtain clean water through community filtration plants. The business model is pay per use.

• In Laos the Sunlabob windfall energy initiative has provided windfall energy in remote rural areas using a pay-per-use approach.

• In Medellin, Colombia, the main electricity provider EPM has developed a pay-asyou-go pre-paid card for customers whose service was cut for non–payment. A percentage of the pre-paid card pays the debt. This initiative has “reconnected” these customers to the system.

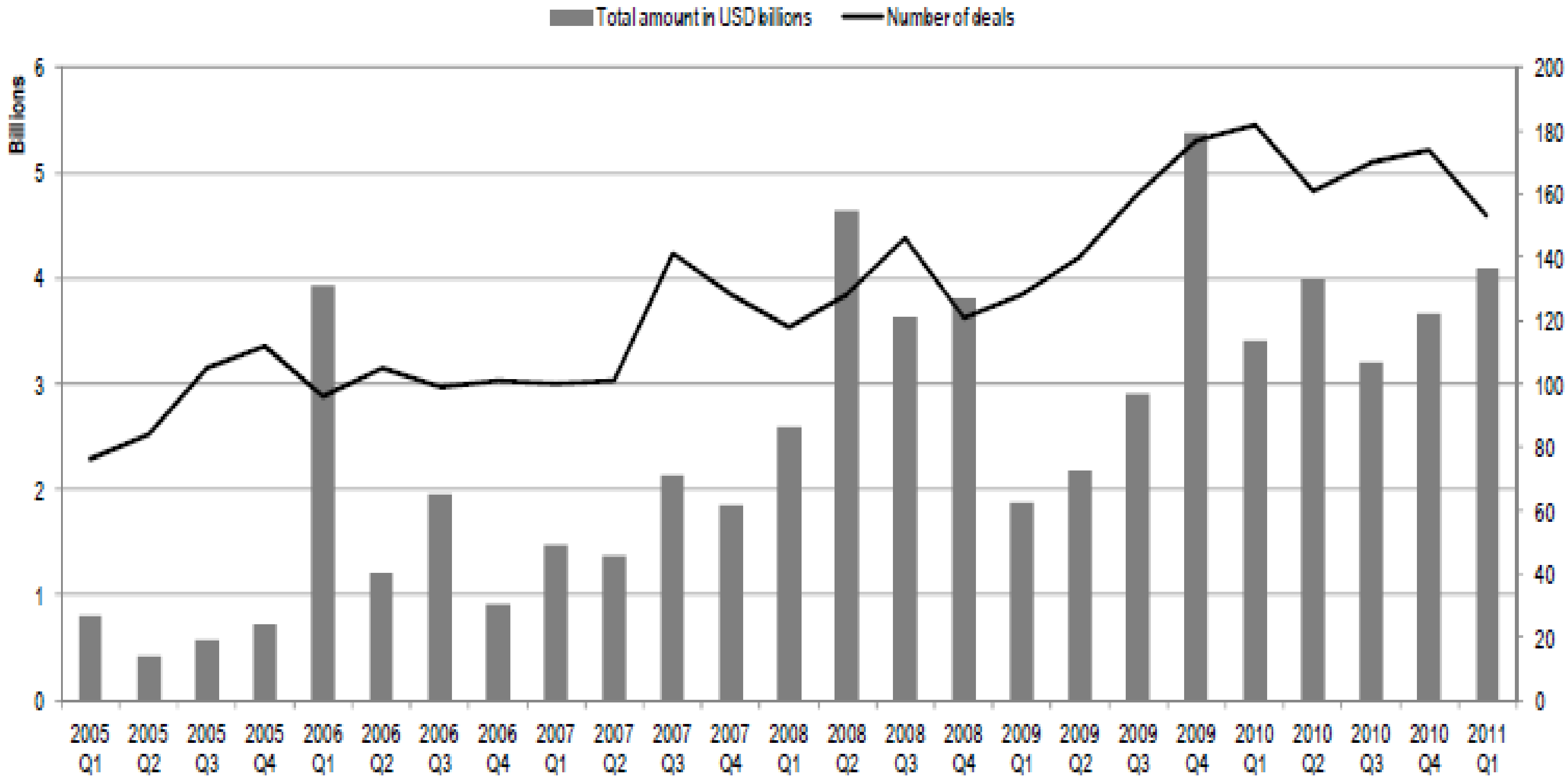
Tiered-pricing: price discrimination whereby higher-income users cross subsidise lower-income users in exchange for extra services or via other forms of market segmentation

• In India Ziqitza operates the 1298 programme, a network of fully equipped advanced and basic life support ambulances. 1298's business model uses a sliding price scale based on a patient's ability to pay, which is determined by the kind of hospital to which patients choose to be taken. Financial sustainability is assured through crosssubsidisation.

Innovation, Economic Growth and Green Growth

- There is some evidence that green innovation is growing:
  - Renewable energy (+24%), electric and hybrid vehicles (+20%), energy efficiency in building and lighting (+11%) experienced much more rapid annual average growth than total patents (+6%) between 1999 and 2008
  - Invention in climate change mitigation technologies such as water and air pollution and waste management have also been growing in recent years
  - Green innovation is also accelerating outside the area of climate change, for example, sustainable chemistry (i.e. biochemical fuel cells, biodegradable packaging, aqueous solvents, selected white biotech, bleaching technologies and green plastics)
- Financing for clean innovation quadrupled in the US between 2005 and 2010.
- Around 1/3 of surveyed firms in OECD countries introduced procedures to regularly identify and reduce environmental impacts
- While evidence is patchy green innovation begins to be gathering pace, driven to some extent by environmental regulation. But it is still a drop in the ocean

Figure 1.9. Global investments in cleantech, 2005-10



Source: OECD calculations based on Cleantech Market Insight Database (*www.cleantech.com*), data cover North America, Europe, Israel, China and India.

Many thanks for your attention!

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