文部科学省 令和元年版科学技術白書より

■第１-１-１表／国・地域別論文数、Top10%補正論文数：上位10か国・地域

Crisis of science and technology nation
(科学技術立国の危機)

全分野	2004 － 2006年 (PY) (平均)		
	論文数		
	分数カウント		
国・地域名	論文数	シェア	順位
米国	228,849	25.7	1
日本	67,696	7.6	2
中国	63,296	7.1	3
ドイツ	53,648	6.0	4
英国	51,976	5.8	5
フランス	38,337	4.3	6
イタリア	31,573	3.5	7
カナダ	29,676	3.3	8
スペイン	23,056	2.6	9
韓国	22,584	2.5	10

全分野	2014 － 2016年 (PY) (平均)		
	論文数		
	分数カウント		
国・地域名	論文数	シェア	順位
米国	273,858	19.3	1
中国	246,099	17.4	2
ドイツ	65,115	4.6	3
日本	63,330	4.5	4
英国	59,688	4.2	5
インド	52,875	3.7	6
韓国	46,522	3.3	7
フランス	45,337	3.2	8
イタリア	44,450	3.1	9
カナダ	39,674	2.8	10

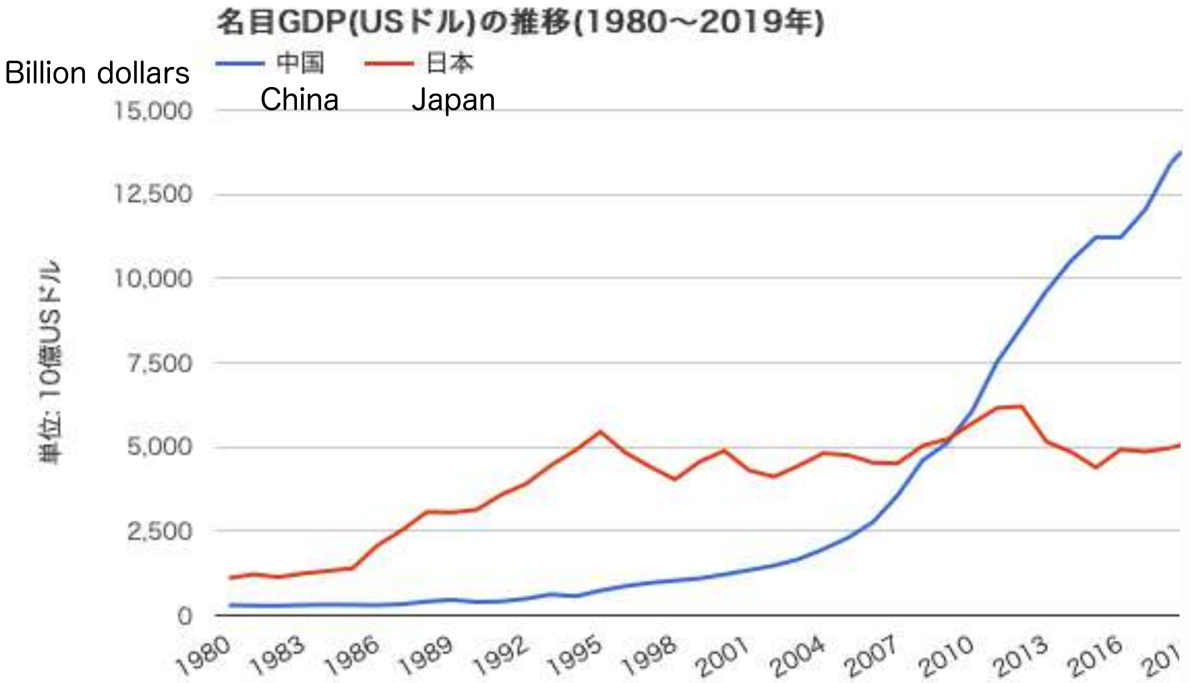
全分野	2004 － 2006年 (PY) (平均)		
	Top10%補正論文数		
	分数カウント		
国・地域名	論文数	シェア	順位
米国	34,127	38.4	1
英国	6,503	7.3	2
ドイツ	5,642	6.4	3
日本	4,559	5.1	4
中国	4,453	5.0	5
フランス	3,833	4.3	6
カナダ	3,392	3.8	7
イタリア	2,731	3.1	8
オランダ	2,146	2.4	9
スペイン	2,093	2.4	10

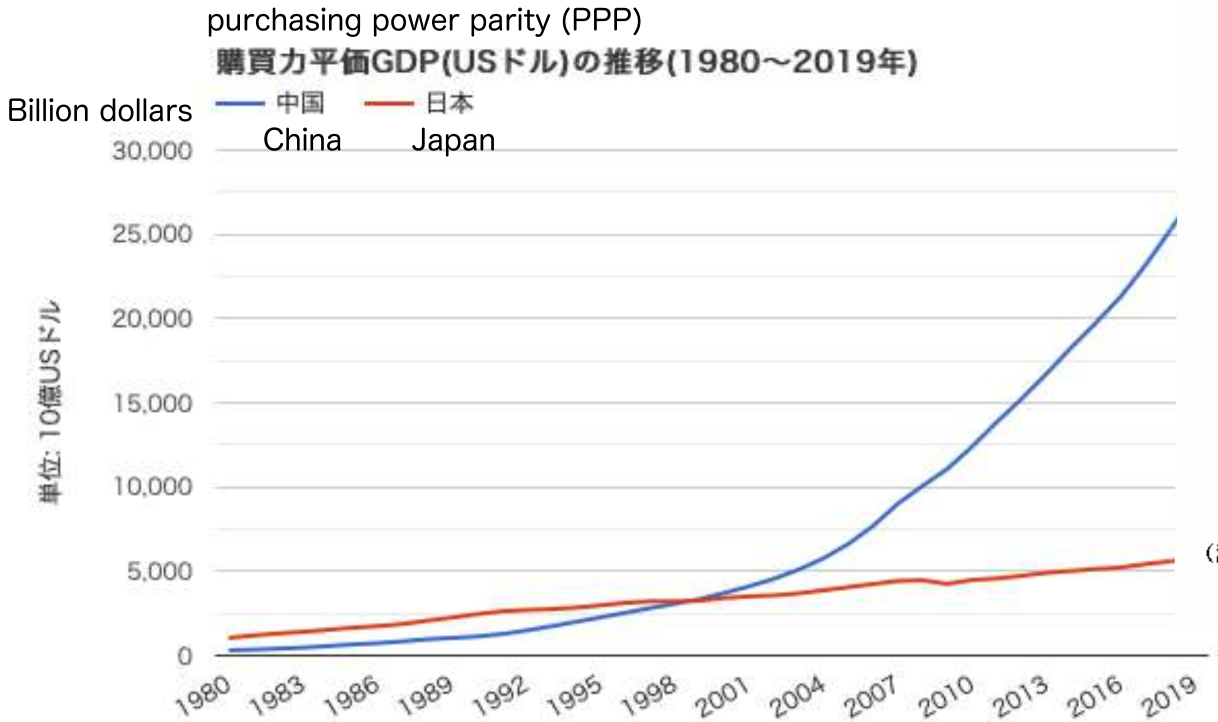
全分野	2014 － 2016年 (PY) (平均)		
	Top10%補正論文数		
	分数カウント		
国・地域名	論文数	シェア	順位
米国	38,736	27.4	1
中国	24,136	17.0	2
英国	8,613	6.1	3
ドイツ	7,755	5.5	4
イタリア	4,912	3.5	5
フランス	4,862	3.4	6
オーストラリア	4,453	3.1	7
カナダ	4,452	3.1	8
日本	4,081	2.9	9
スペイン	3,609	2.5	10

注：分数カウント法を用いて集計。分数カウントとは、機関レベルでの重み付けを用いた国単位での集計である。例えば、日本のＡ大学、日本のＢ大学、米国のＣ大学の共著論文の場合、各機関は３分の１と重み付けし、日本３分の２件、米国３分の１件と集計する。したがって、１件の論文は、複数の国の機関が関わっていても１件として扱われる。
資料：科学技術・学術政策研究所「科学技術指標2018」調査資料-274（平成30年８月）（クラリベイト・アナリティクス社　Web of Science XML（ＳＣＩＥ、2017年末バージョン）を基に、科学技術・学術政策研究所作成）

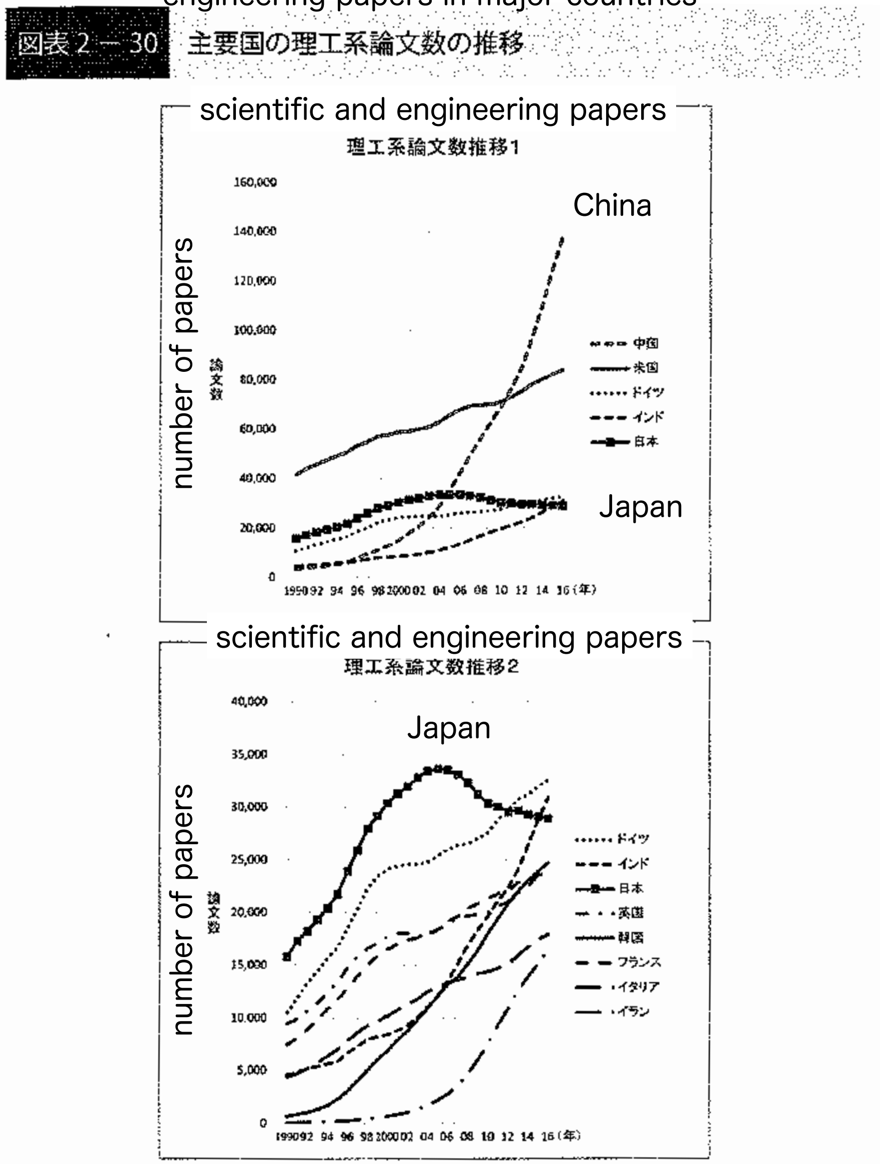
1　被引用数Top10％補正論文数とは、被引用数が各年各分野で上位10％に入る論文の抽出後、実数で論文数の10分の１となるように補正を加えた論文数を指す。

世界経済のネタ帳、https://ecodb.net/exec/trans_country.php?type=WEO&d=NGDP&c1=JP&s=&e=





Changes in the number of scientific and engineering papers in major countries



(注) クラリベイト・アナリティクス社 InCites Benchmarking より 2018 年 2 月 13 日データ抽出。文献種原著、分野分類法 ESI、整数カウント、3 年移動平均値（表示年から過去 3 年間）。「理工系」とは、物理学、化学、材料科学、工学の 4 分野の合計。

科学立国の危機、豊田長康 著

“Crisis of science nation” by Nagayasu Toyoda

読売新聞教育ネットワーク異見交論64 「思考停止の改革」から脱却せよ

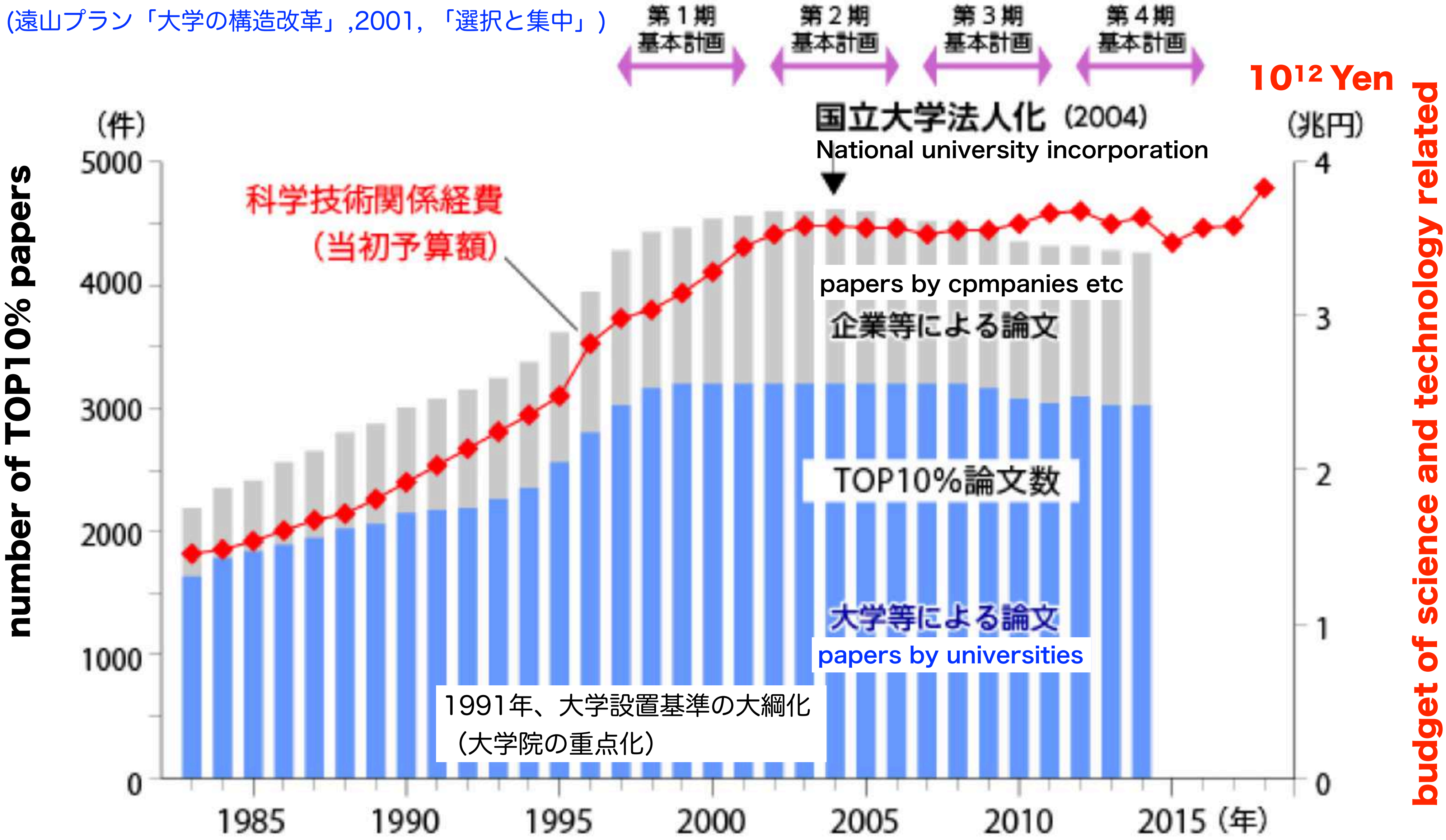
浜口道成氏（科学技術振興機構理事長）

「科学技術はきわめて正直だ。平均的な人間の成果は、投資した金額に比例している。一定の相関性がある。必要十分条件ではないが、必要条件であるのは確か。エビデンスベースの議論が必要となる。」

■ 日本の科学技術関係経費と論文数の推移 ※文部科学省資料をもとに作成

「産出量（TOP10%論文数）がプラトー（停滞状態）に達したのは98年、99年ごろ。法人化の5、6年前にはすでに始まっていた。」

(遠山プラン「大学の構造改革」,2001，「選択と集中」）



Deloitte.

デロイトは、「世界モバイル利用動向調査」(Global Mobile Consumer Survey, 以下MCS)と題して、日本を含めたグローバルでの調査を毎年実施している

This report (the “Report”) has been prepared by Deloitte MCS (“Deloitte”) for the Engineering and Physical Sciences Research Council (“EPSRC”) in accordance with the contract with them dated 11th May 2012.

… **Mathematical sciences are vital for the future prosperity of the UK and its position in a world economy; this report tells us why.**

Measuring the Economic Benefits of Mathematical Science Research in the UK

Final Report

November 2012

This study by Deloitte considers, qualitatively, the ways in which MSR (Mathematical Science Research) influences economic performance in the UK and then quantifies the economic value of MSR in terms of direct employment supported and Gross Value Added (GVA) generated in 2010. Our approach has been to first identify those jobs that can be classified as mathematical science occupations and then to use publicly available data to examine how these occupations are distributed across different sectors of the UK economy. These insights on direct employment are then inputted into a bespoke Deloitte model to calculate GVA. Where appropriate, this quantitative analysis has been supplemented by qualitative analyses.

The Quantifiable Impacts of MSR in 2010 – a 60-second summary

The impact of Mathematical Science Research (MSR) extends across all aspects of the UK economy

Employment

Number of individuals in mathematical science occupations

2.8 m

around 10% of all jobs in the UK

analogous to GDP, except that it only includes relevant value added at each stage of production.

Gross Value Added

Direct GVA associated with MSR

£208 bn

around 16% of total UK GVA

Productivity of individuals in mathematical science occupations (as measured by GVA per worker) is double the UK average

MSR is most embedded in research-led industries but its contribution to employment is also high in absolute terms in other sectors such as construction

Mathematical science occupation jobs as % of total employment in sector

- R&D: 80%
- Computer Services: 70%
  largest 350,000
- Aircraft & Spacecraft: 50%
- Pharmaceuticals: 50%
- Architectural Activities and Technical Consulting: 40%

Top 5 sectors for mathematical science occupations (absolute numbers)

- Computer Services: 347k
- Public Administration and Defence: 257k
- Architectural Activities and Technical Consulting: 213k
- Construction: 204k
- Education: 189k

MSR's contribution to GVA is largest in sectors in higher productivity sectors that also have a high employment or customer base

Direct MSR GVA contribution ....

- Banking & Finance: £27 bn
- Computer Services: £19 bn
- Pharmaceuticals: £16 bn
- Construction: £13 bn
- Public Administration and Defence: £12 bn

Productivity (労働生産性）and Direct GVA impact

Productivity (as measured by direct GVA per worker) is significantly higher in mathematics science occupations compared to the UK average (approximately **£74,000** versus **£36,000**), and as such **the direct GVA impact** of mathematical science research in 2010 is proportionately higher than the share of direct employment (**16 %, GVA** versus **10 % employment**).

GDP and **GVA**

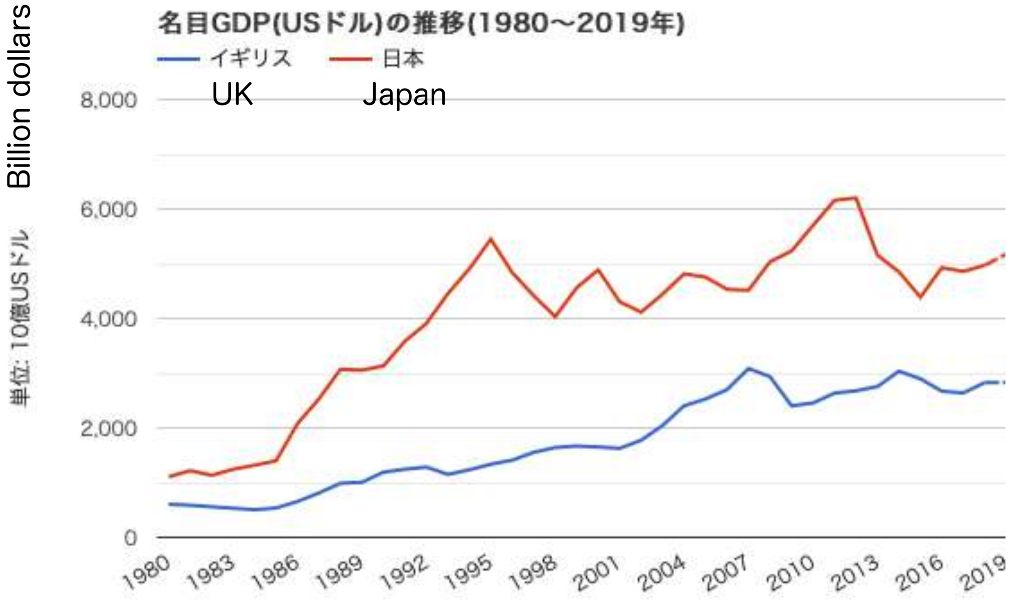
In economics, gross value added (GVA) is the measure of the value of goods and services produced in an area, industry or sector of an economy. In national accounts GVA is output minus intermediate consumption; it is a balancing item of the national accounts' production account. (OECD, Wikipedia)

GVA + tax - grant = GDP (GVA + 税 - 補助金 = GDP, Gross Domestic Product)

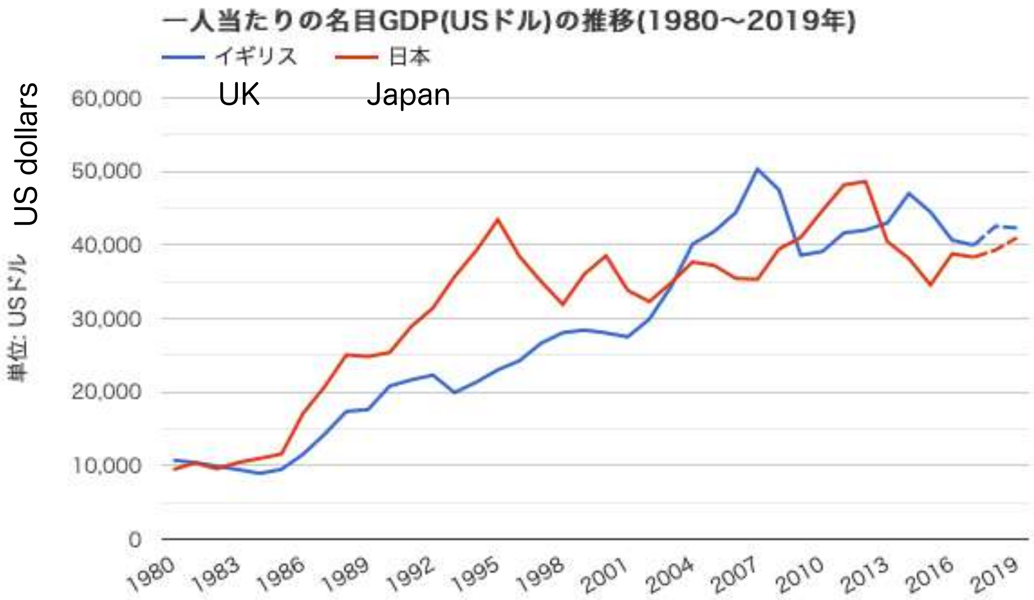
In addition, **indirect employment impact**: changes in employment numbers in associated industries that supply inputs to businesses generating and applying mathematical science research (sometimes referred to as ‘supply chain’ impacts); and **induced employment impact**: the spending by households that result in changes to employment numbers to direct and indirect impacts. (Appendix 1)

世界経済のネタ帳、https://ecodb.net/exec/trans_country.php?type=WEO&d=NGDP&c1=JP&s=&e=

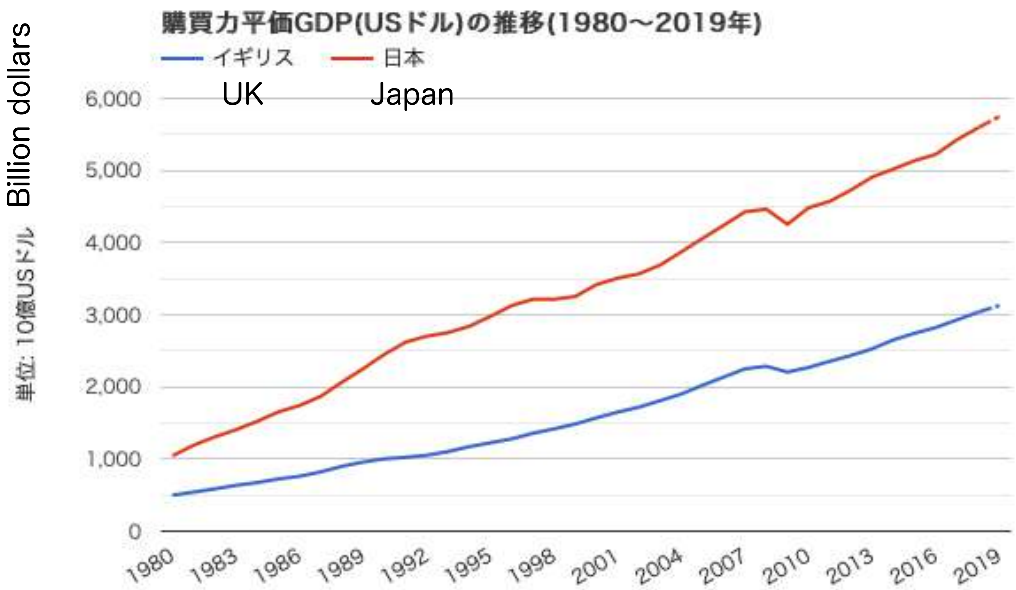
Nominal GDP



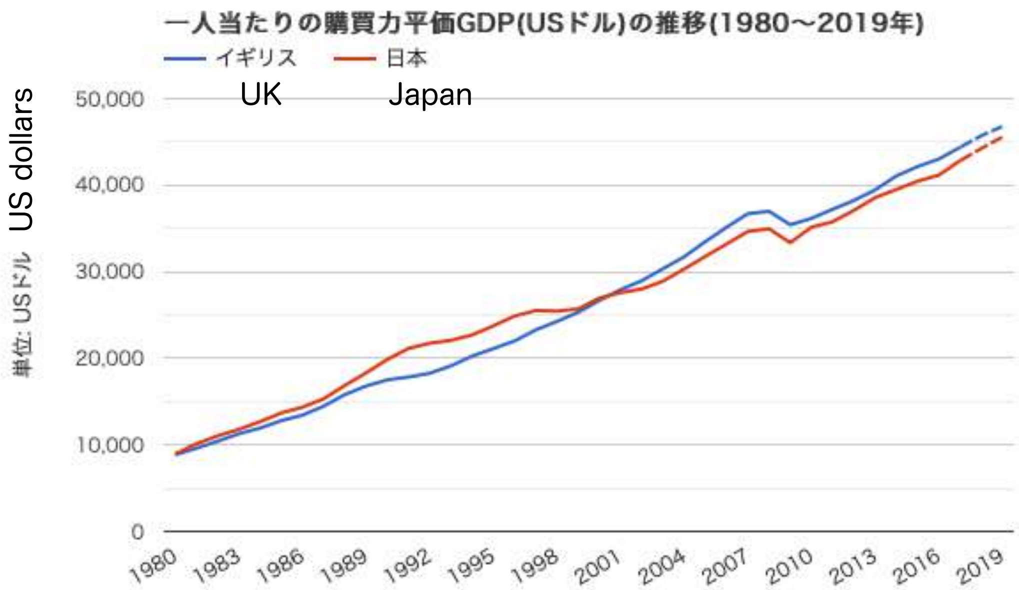
Nominal GDP per capita



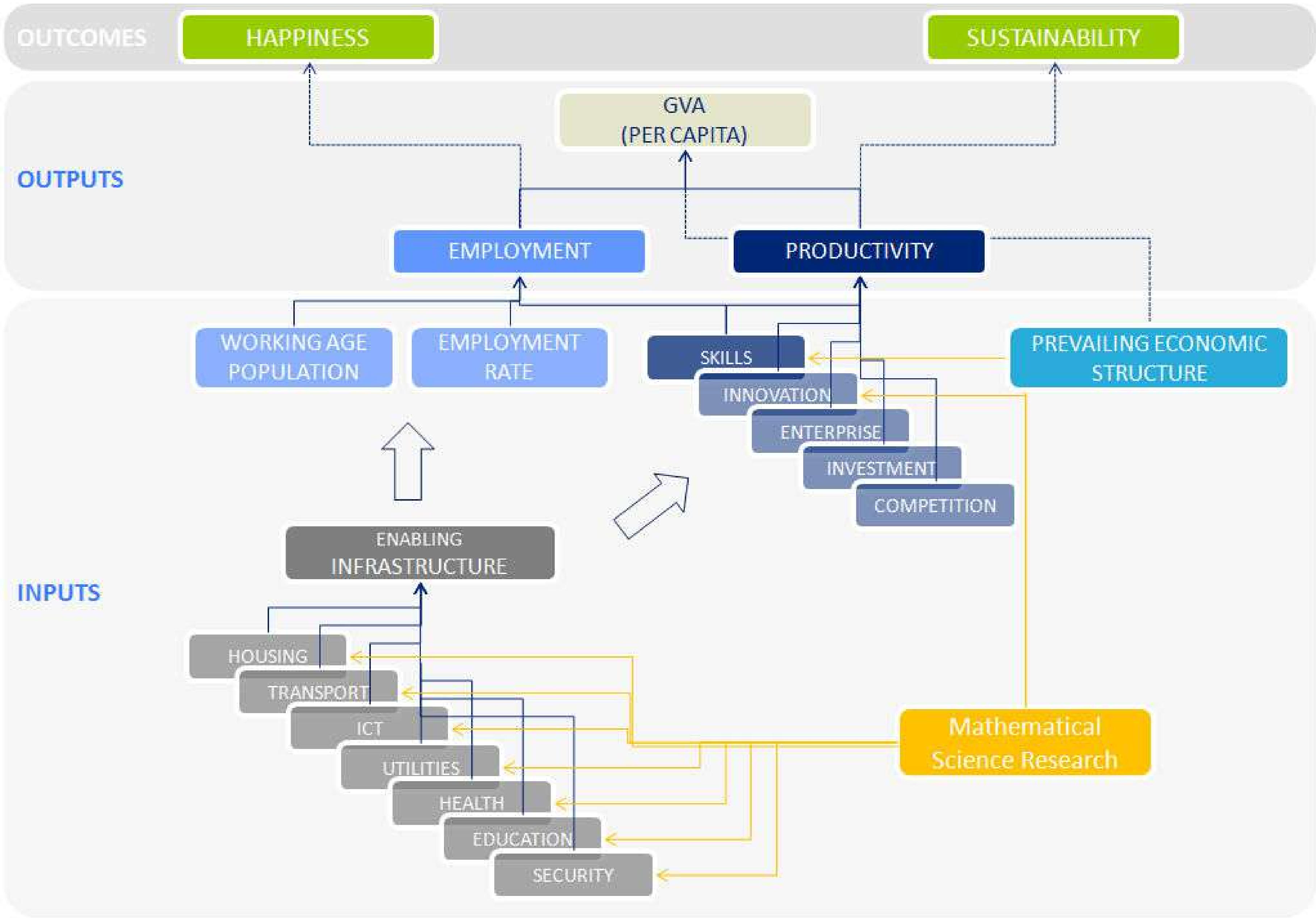
purchasing power parity (PPP) GDP



purchasing power parity (PPP) GDP per capita



MSR as a generic driver of long-term economic growth



Source: Deloitte

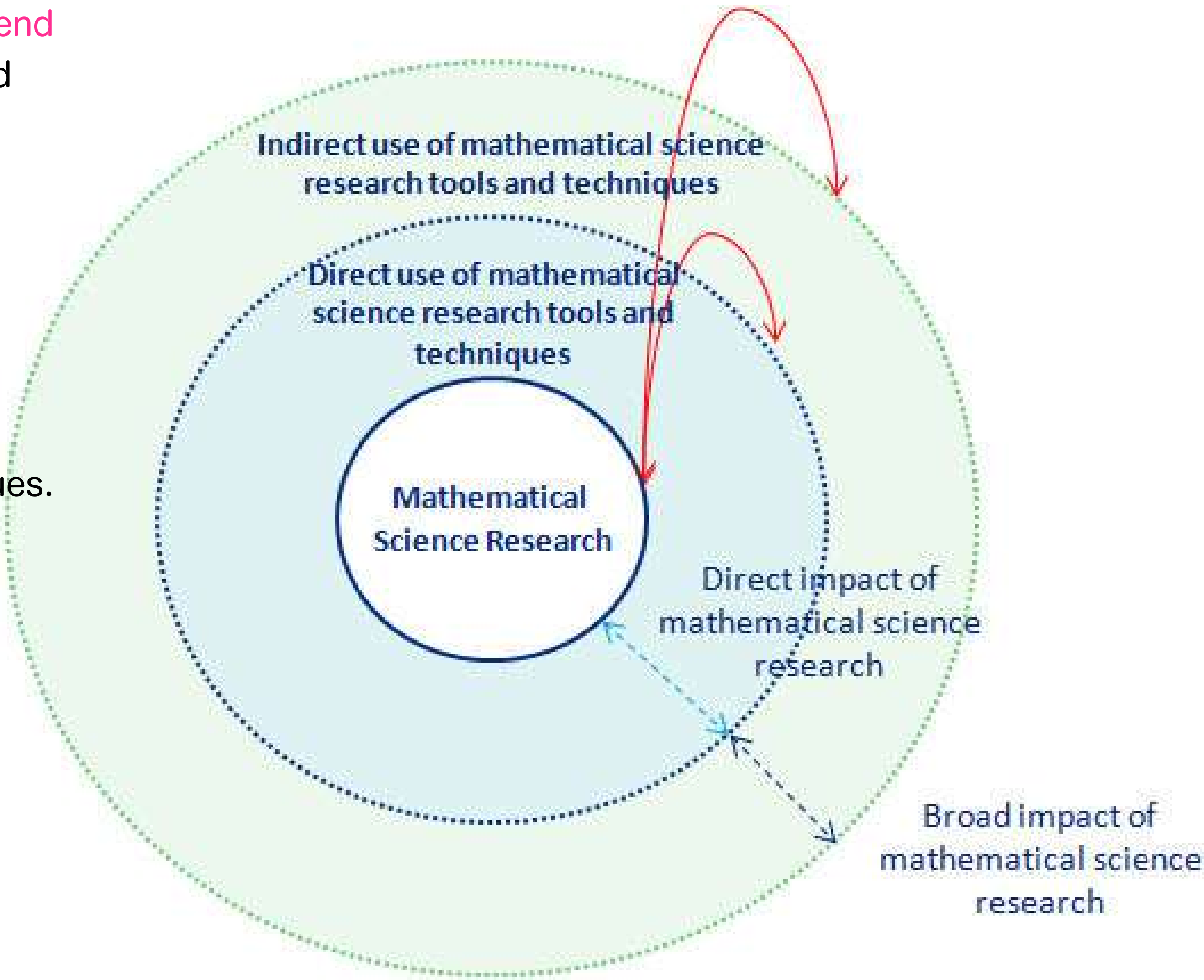
…full economic impact of a given piece of research may not be felt immediately due to **time lags**; indeed it may be many years until there is an impact on the economy. e.g. Radon transformation in topography, Johann Radon in 1917, for CT scan etc.

1 Introduction

Definition of MSR

For the purposes of this study we use the working definition of MSR as being high-end research in mathematical sciences carried out in academic institutions, research centres, businesses, individuals and Government that adds to the store of accumulated mathematical knowledge. Mathematical Science occupations are therefore those occupations which either entail MSR, or which directly require the usage of MSR-derived tools and techniques.

1. **Mathematical science research is carried out which…**
2. **… can lead to new tools and techniques being developed and applied that….**
3. **… eventually can have an economy wide impact as these tools and techniques become commonplace**

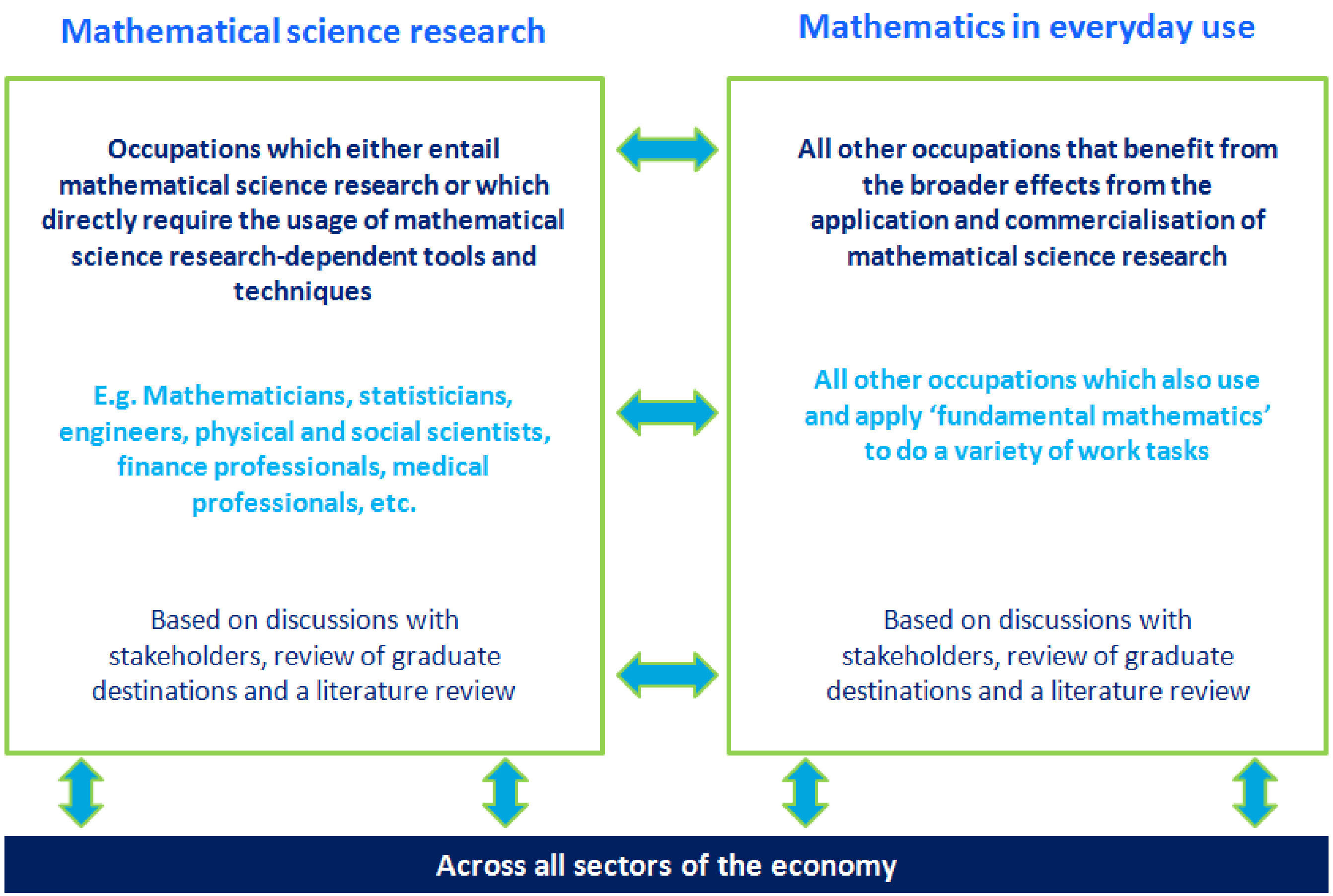


Source: Deloitte

Mathematical research and the everyday use of mathematics

Figure 1.2.1 summarises our approach to distinguishing the economic impact of MSR from mathematics more generally using occupation classifications[18] created by the Office of National Statistics.

Figure 1.2.1: Mathematical science research and mathematics in everyday use

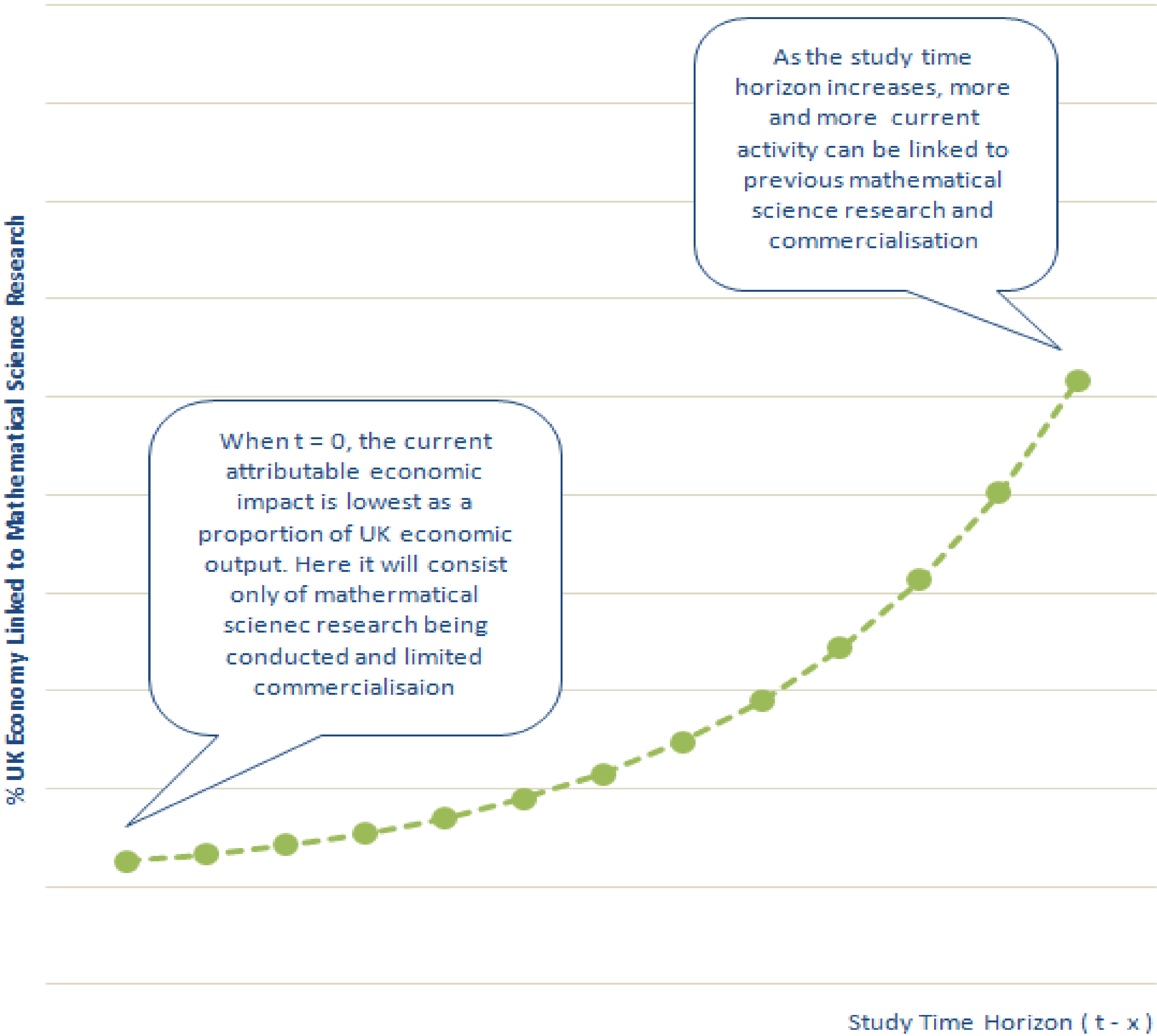


Source: Deloitte

[18]These occupation classifications are based on the Office of National Statistics' Standard Occupational Classification (SOC) system which is common classification framework of occupational information for the UK on the basis of skill level and skill content. At the most detailed level (4 digit) which we have used this contains 70 different occupational types. **: occupation-based definition of MSR**

Figure 1.2.2: Mathematical science research over an extended time horizon

MSR to commercialisation (商業化, 営利化, 商品化)



Source: Deloitte

Our approach

⇒ **Identifying occupations directly involved in the generation and application of MSR ('MSR occupations')**: as discussed above, using the 2000 Standard Occupational Classification (SOC) codes, a list of occupations that could be classed as 'mathematical science occupations' was identified – this list, which can be found in the appendix, was based on our literature review, a review of graduate destinations and stakeholder comments. 70 occupations were identified as mathematical science occupations.

⇒ **Allocating these occupations across the different sectors of the UK economy**: using the SIC-SOC matrix provided by the ONS(Office for National Statistics), we identified how these mathematical science occupations were distributed across the 600+ sectors of the economy. Some adjustments were made to each sector in order not to over-state mathematical science occupation employment numbers, i.e. where only a proportion of those in mathematical science occupations are likely to be directly involved in the application of MSR. Details of such adjustments can be found in the appendix.

Following these adjustments, we were able to reach **our estimates of the direct number of individuals in mathematical science occupations** in the in the UK in 2010.

⇒ **Applying a UK Input-Output model to calculate GVA attributable to MSR**.

SIC : Standard Industrial Classification for sectors of the economy
SOC : Standard Occupational Classification for employments in occupations

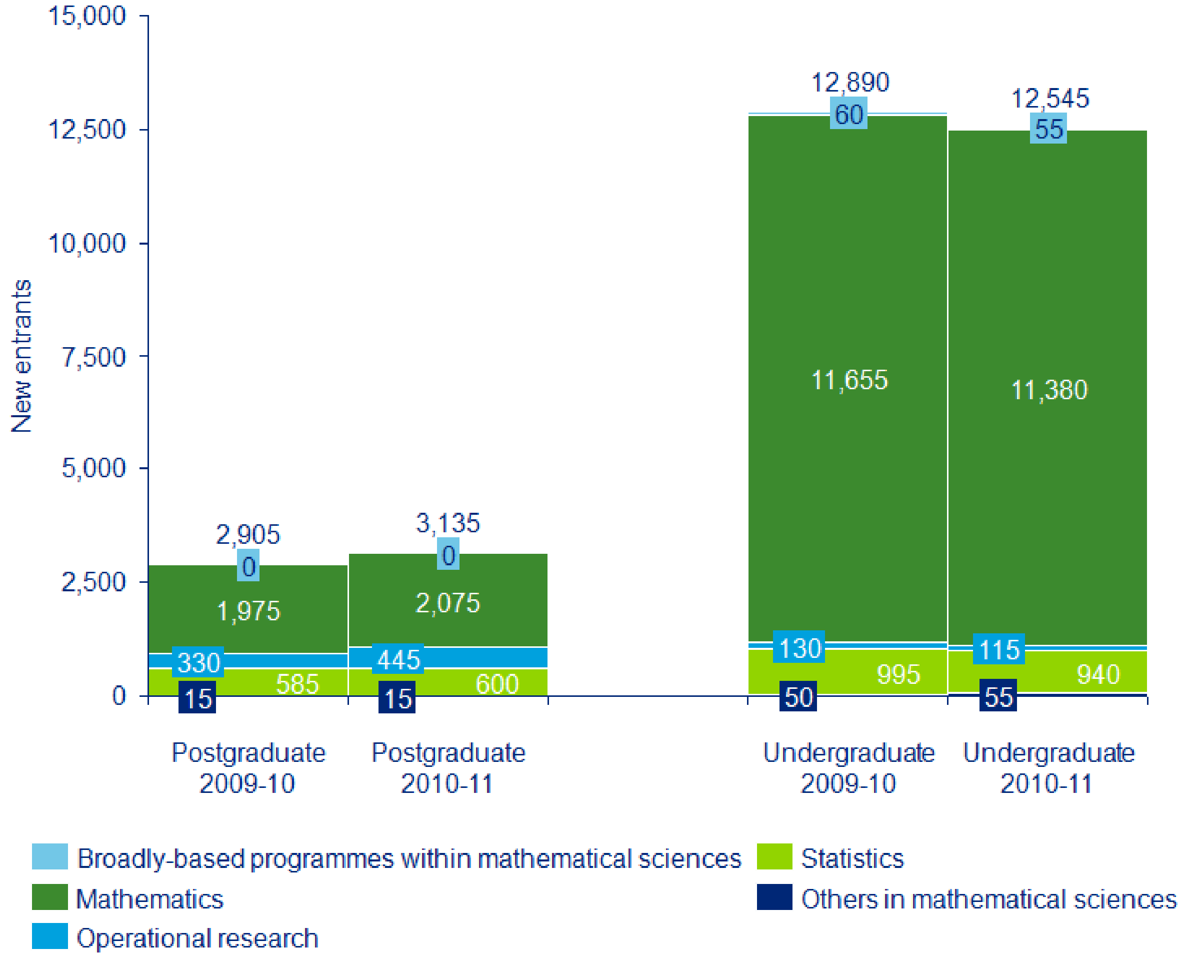
UK Input-Output model : UK Domestic Use Matrix with 100+ sectors, so it is necessary to convert the SIC categories into DUM categories for GVA and direct employment attributable to MSR.

2 A framework for considering mathematical science research and the UK economy

2.1 The mathematical sciences landscape in the UK

Data on new entrants to undergraduate and postgraduate courses also remains strong, though the numbers for undergraduates fells lightly between 2009-10 and 2010-11

Figure 2.1.1: New entrants to undergraduate and postgraduate mathematical science programmes[28], 2009-10 to 2010-11

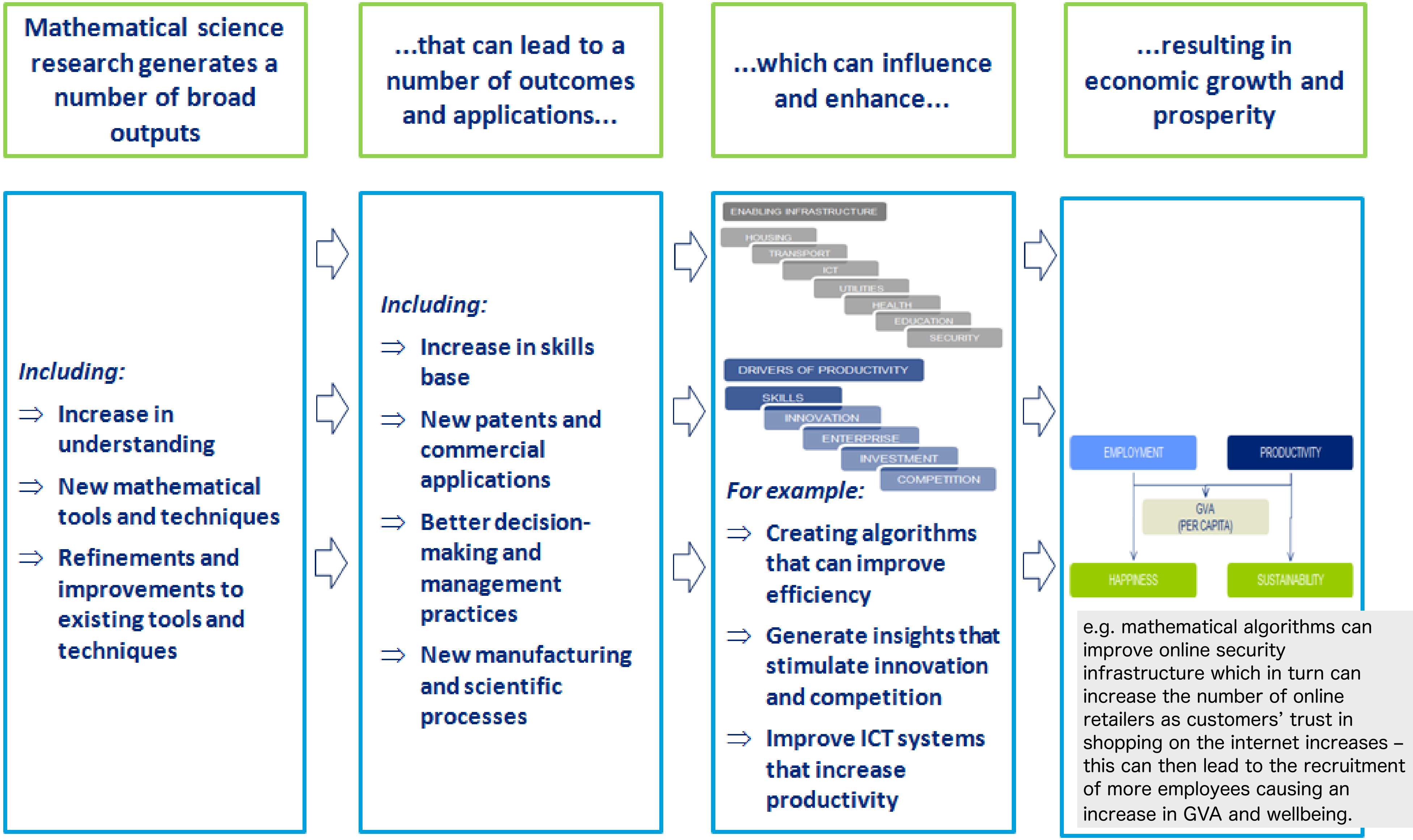


Source: Deloitte using HESA data

with 3.9 % of world researchers and 3 % of world gross expenditure on R&D, the UK produces 6.4% of all mathematical science articles

MSR cuts across the long-term economic growth drivers as shown below in Figure 2.2.1.

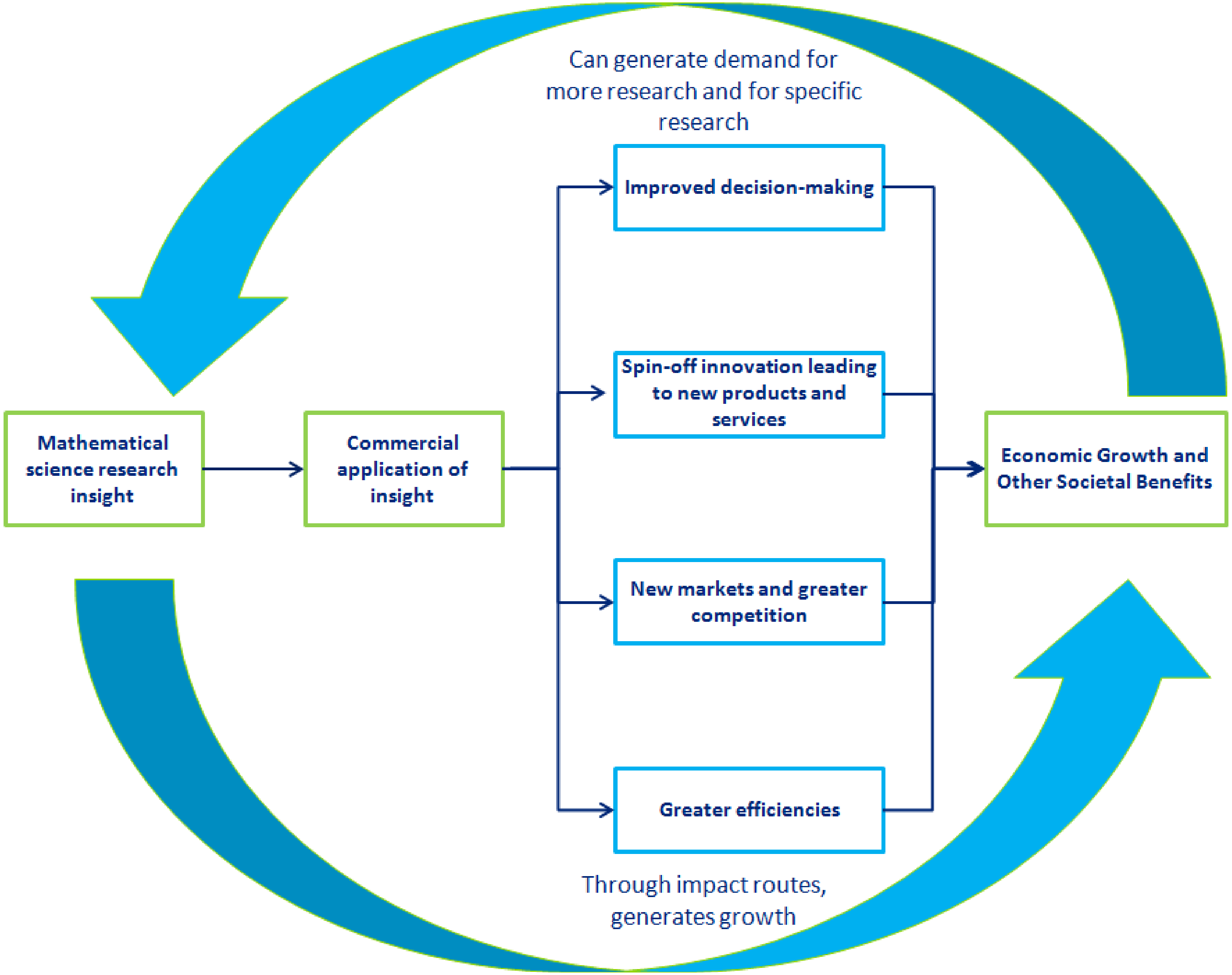
Figure 2.2.2: Economic impact chain for UK mathematical science research



Source: Deloitte

3 Ways in which mathematical science research can benefit the UK economy

Figure 3.1.1: Mathematical science research virtuous circle[34]



Source: Deloitte drawing on insights by Rowan Douglas

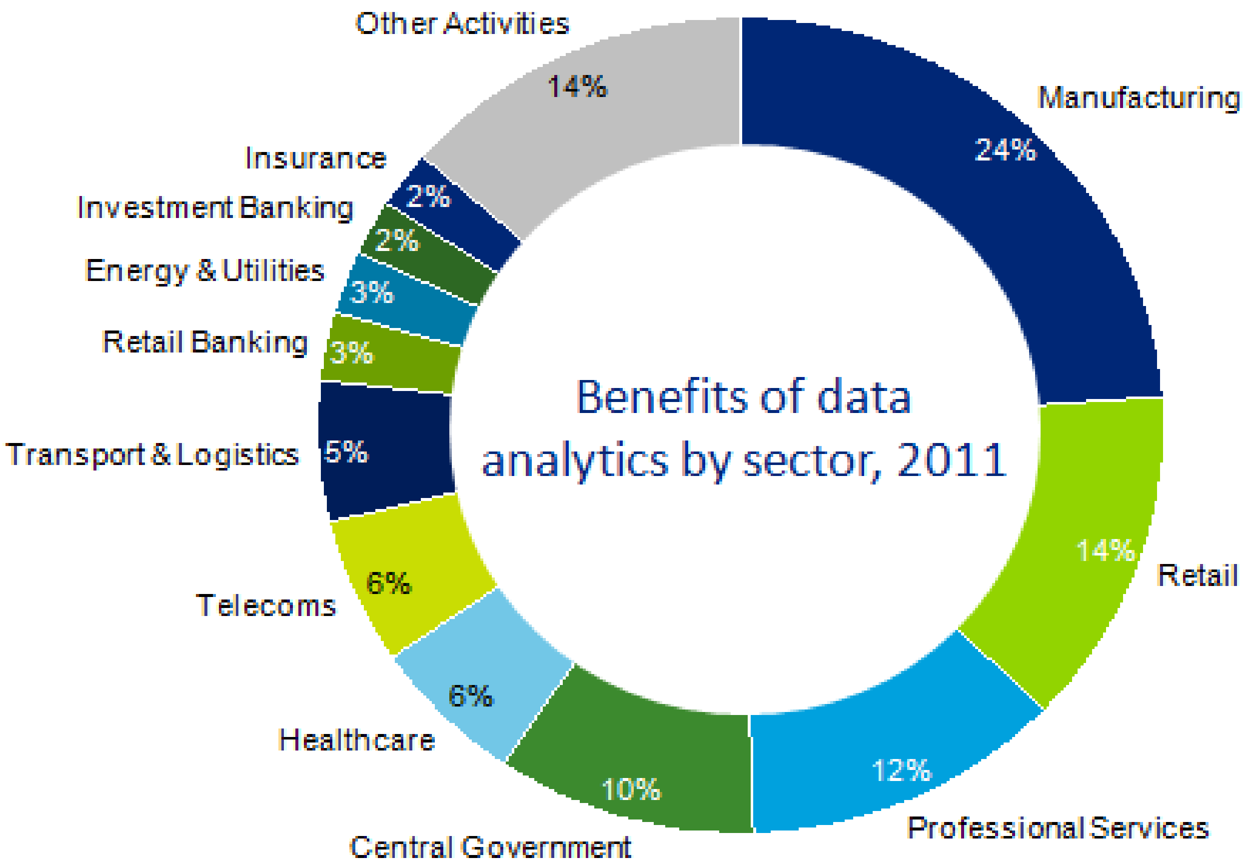
The company employs a number of mathematics and applied science PhDs and its algorithms have benefit a number of industries including:

⇒ Finance: to assist in portfolio construction and optimization;

⇒ Business intelligence and business analytics: to assist in making forecasts, identifying area of opportunity and guiding investment decisions; and

⇒ Aeronautics, utilities and manufacturing: using algorithms to model real world events and optimise processes.

Figure 3.1.2: Estimated spread of benefits from data analytics in the UK



Source: SAS

UK economy benefits from mathematical science through:

⇒ building the ‘information infrastructure’ upon which a myriad of businesses and individuals rely;

⇒ supplying the tools and techniques to analyse and interpret large datasets;

⇒ providing a public good in modelling the impacts of natural disasters and testing drugs;

⇒ contributing to national security and other necessary ‘public goods’ through advanced data security tools and infrastructure provision;

⇒ creating robust forecasts to address uncertainty and allow for better planning;

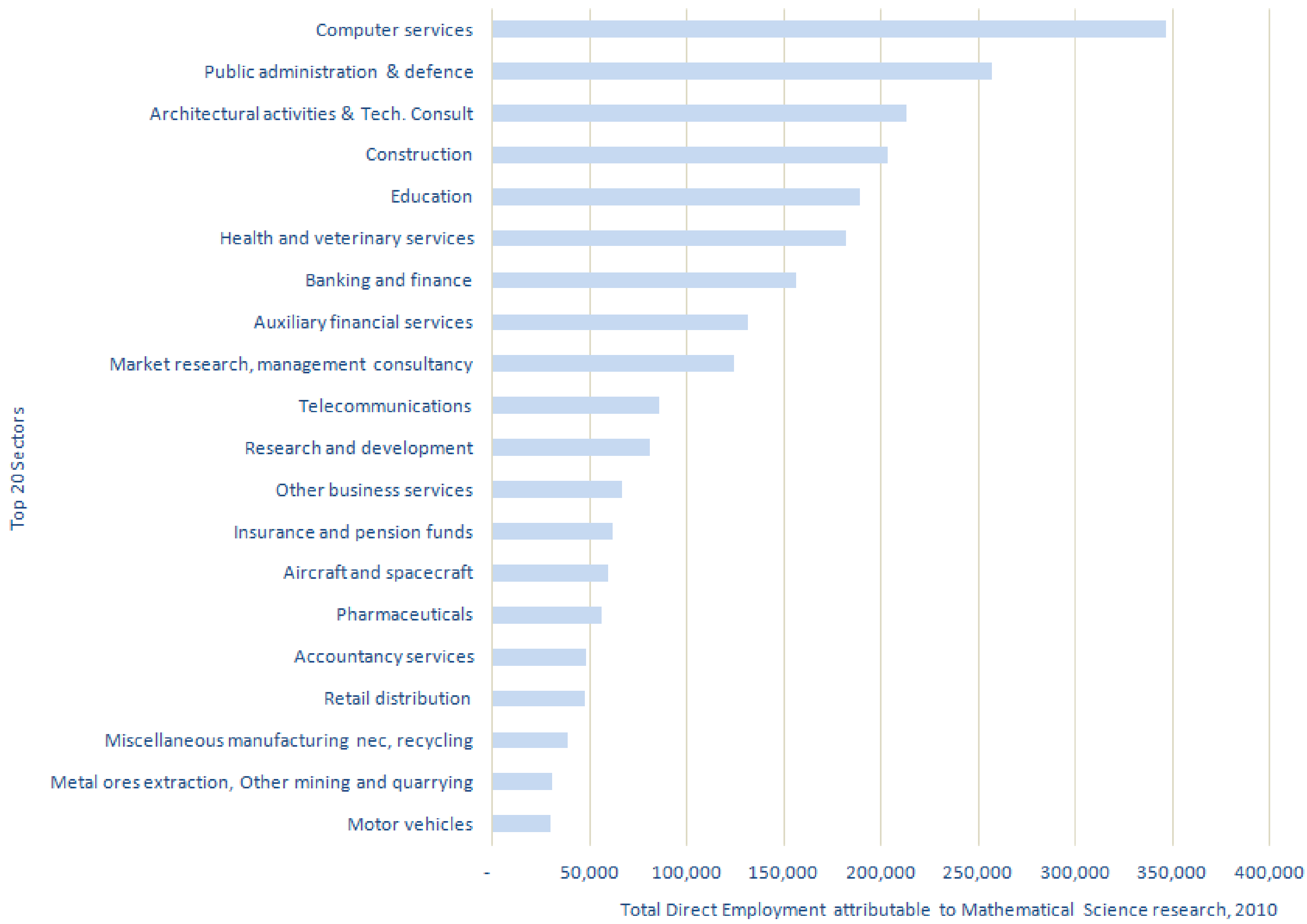
⇒ optimising processes to increase efficiency.

SAS estimated that data analytics of ‘big data’, which heavily uses algorithms, contributed £25.1 billion to the UK economy in 2011. This is expected to reach £40.7 billion p.a. by 2017 as more companies adopt big data technologies (not just cutting edge companies in technical sectors). This is estimated to lead to the creation of an additional 58,000 new jobs over the next 6 years.

4 Mathematical science research – direct economic contribution

Direct employment in the UK attributable to mathematical science research is over 2.8 million

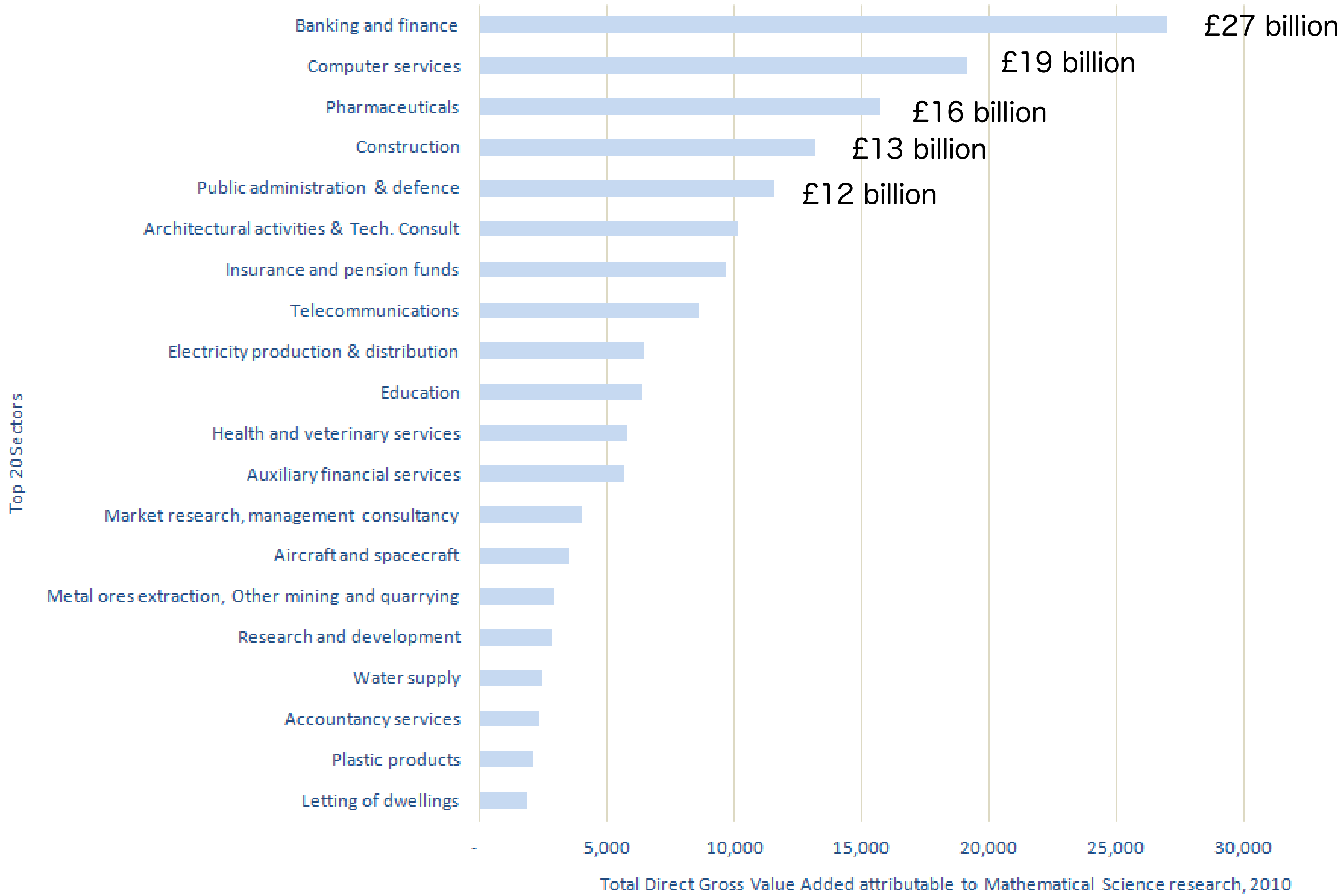
Figure 4.1.1: Top 20 sectors for direct employment in the UK, 2010



Source: Deloitte using ONS data

Our analysis suggests that **the GVA attributable to the direct application and generation of mathematical science research** in the UK in 2010 was approximately £208 billion, or around 16 per cent of total UK GVA.

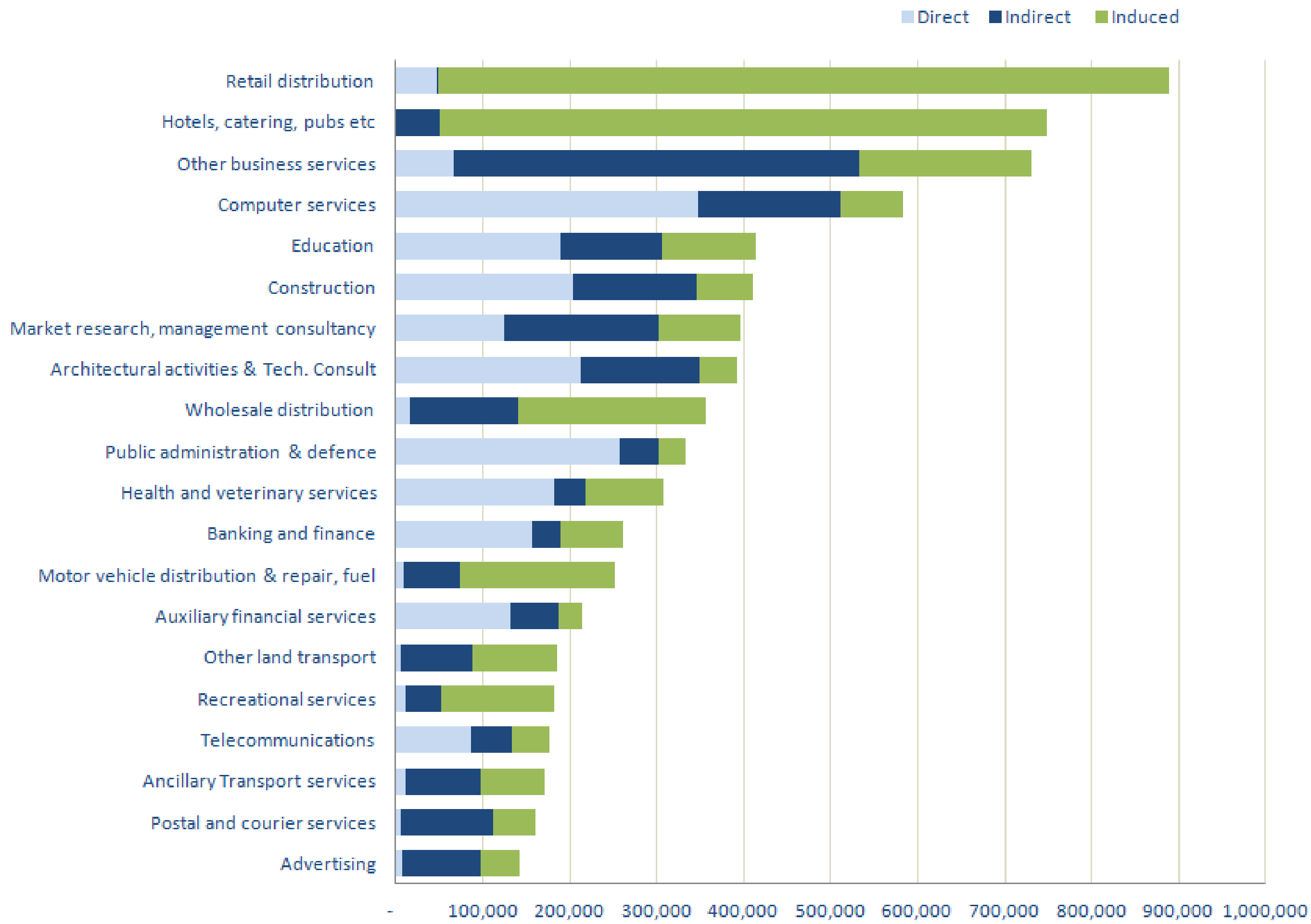
Figure 4.2.1: Top 20 sectors for direct mathematical science GVA in the UK, 2010, £m



Productivity (as measured by GVA per worker) is significantly higher in mathematics science occupations compared to the UK average - £74,000 compared to £36,000

5 Appendix 1: Indirect and induced economic impacts

Figure 5.1.1: Total employment attributable to mathematical science research in the UK, by sector, 2010

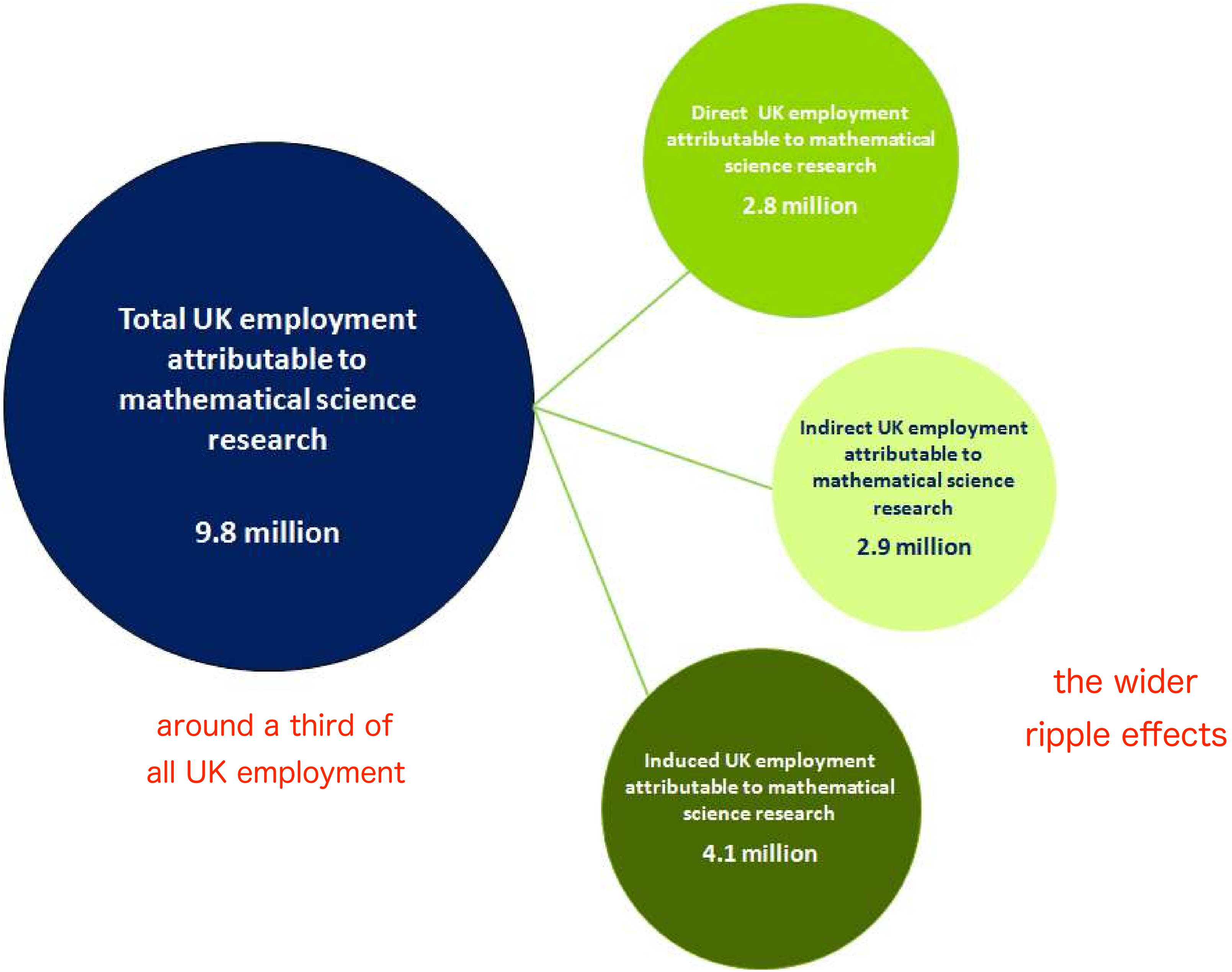


Source: Deloitte using ONS data

Indirect employment impact: changes in employment numbers in associated industries that supply inputs to businesses generating and applying mathematical science research (sometimes referred to as 'supply chain' impacts); and

Induced employment impact: the spending by households that result in changes to employment numbers to direct and indirect impacts.

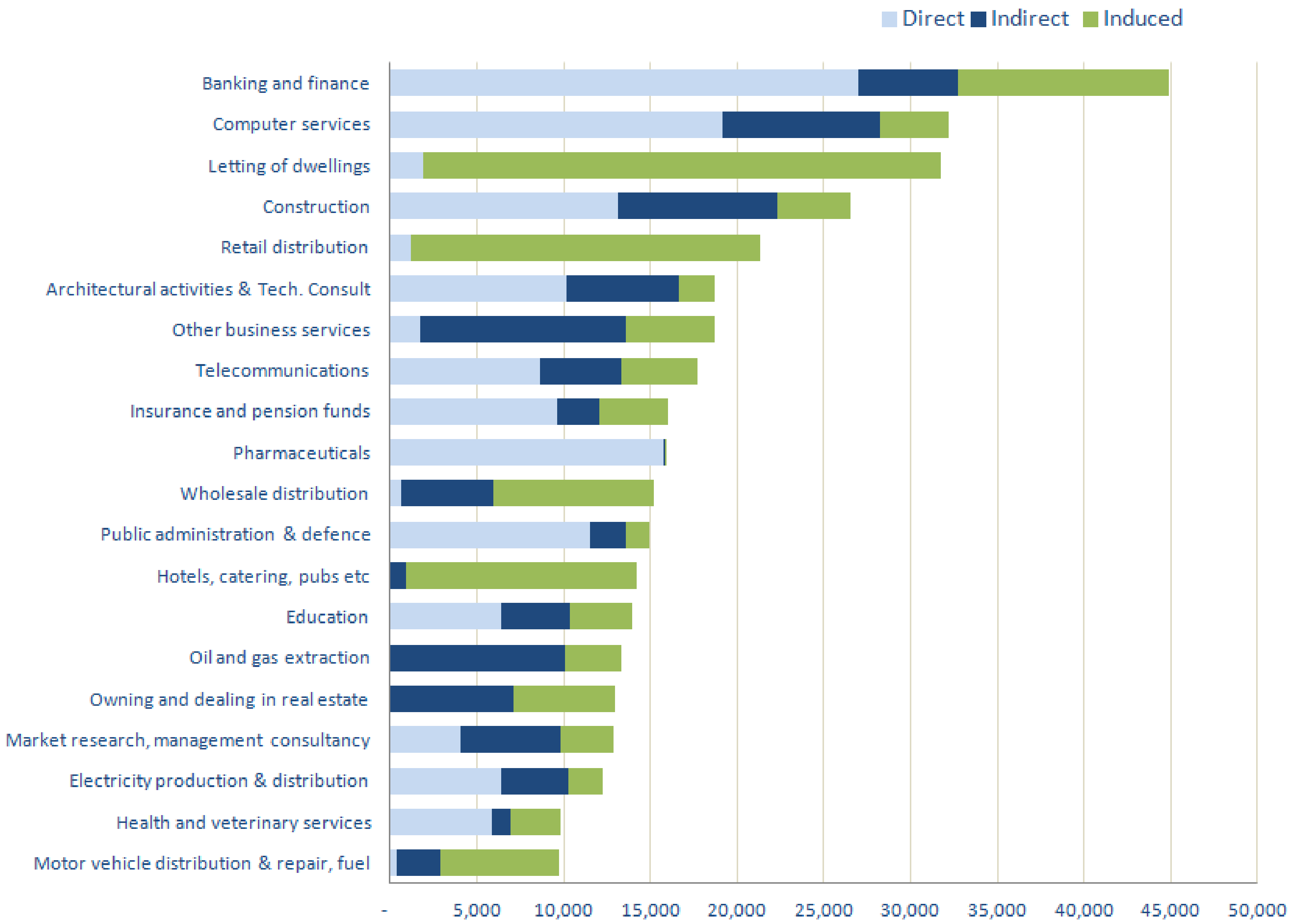
Figure 5.1.2: Breakdown of mathematical science research in the UK, 2010



Source: Deloitte using ONS data (numbers rounded to 1 decimal point)

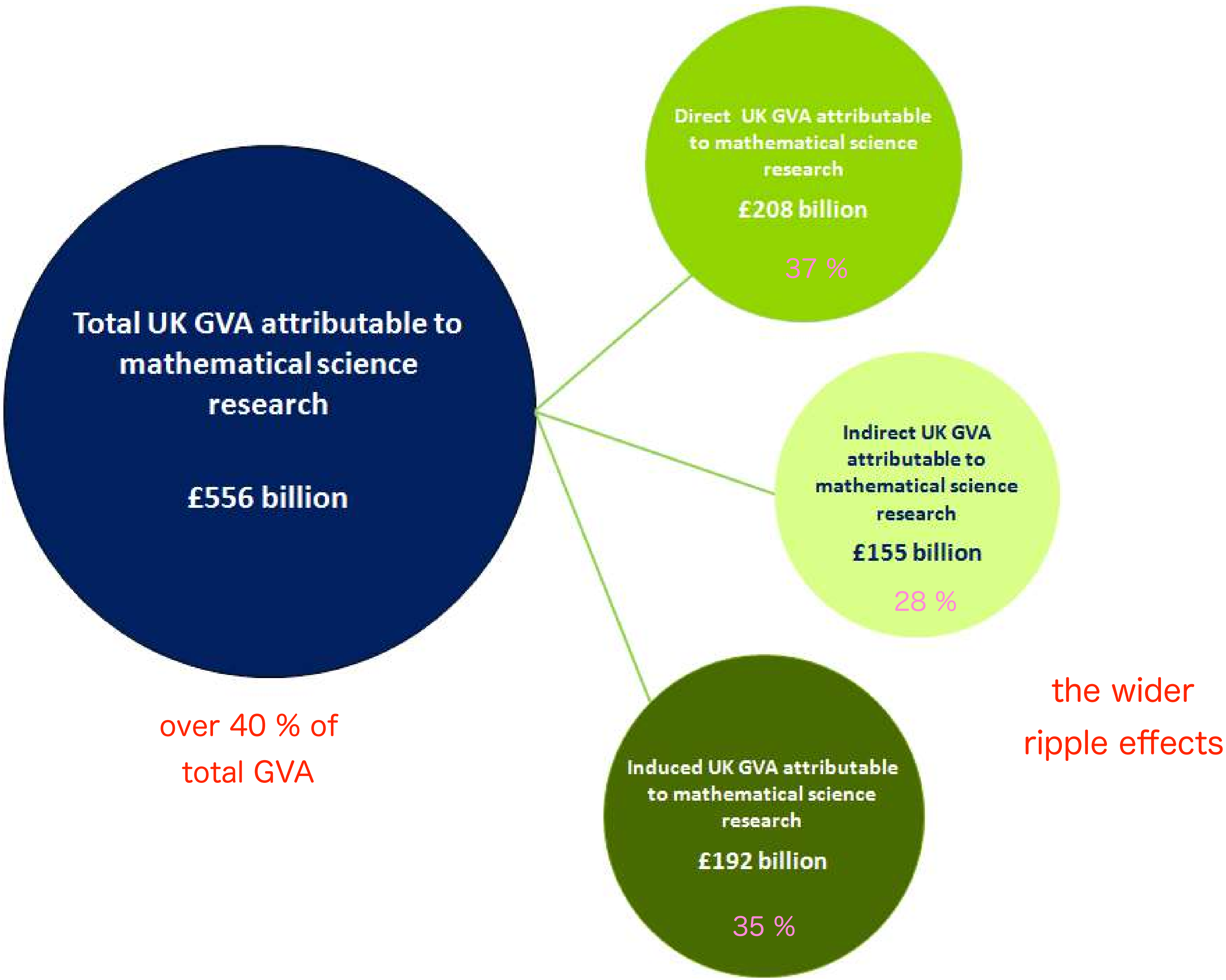
Incremental GVA

Figure 5.2.1: Top 20 sectors for total GVA in the UK, 2010, £m



Source: Deloitte using ONS data

Figure 5.2.2: Breakdown of mathematical science research in the UK, 2010



Source: Deloitte using ONS data (numbers rounded to 1 decimal point)

6 Appendix 2: Quantification methodology

the 2000 Standard Occupational Classification (SOC) produced by theThe Office of National Statistics (ONS) to list all the occupation categories in the UK. The SOC splits all occupations into groups according to their skill level and skill content. The most detailed level (4-digit SOC) contains over 350 occupations and this is the level we have used. … 70 4-digit SOC categories were identified as being mathematical science occupations.

Figure 6.1.1.: Identified mathematical science occupations

Mathematical science occupations from SOC (2000)	
1111 Senior officials in national government	2211 Medical practitioners
1112 Directors & chief execs of major organisations	2212 Psychologists
1113 Senior officials in local government	2213 Pharmacists & pharmacologists
1121 Prod. works & maintenance managers	2215 Dental practitioners
1123 Managers in mining and energy	2311 Higher education teaching professionals
1131 Financial managers & chartered secretaries	2317 Registrars & senior administrators of educational establishments
1132 Marketing and sales managers	2321 Scientific researchers
1133 Purchasing managers	2322 Social science researchers
1136 Information & communication technology managers	2329 Researchers not elsewhere classified
1137 Research and development managers	2421 Chartered and certified accountants
1141 Quality assurance managers	2422 Management accountants
1151 Financial institution managers	2423 Management consultants, actuaries, economists & statisticians
1181 Hospital and health service managers	2431 Architects
2111 Chemists	2432 Town planners
2112 Bio scientists and biochemists	2433 Quantity surveyors
2113 Physicists, geologists & meteorologists	2434 Chartered surveyors (not quantity surveyors)
2121 Civil engineers	2441 Public service administrative

Mathematical science occupations from SOC (2000)	
	profs
2122 Mechanical engineers	3111 Laboratory technicians
2123 Electrical engineers	3112 Electrical & electronic technicians
2124 Electronics engineers	3113 Engineering technicians
2125 Chemical engineers	3114 Build & civil eng technicians
2126 Design and development engineers	3115 Quality assurance technicians
2127 Production and process engineers	3119 Science & eng technicians not elsewhere classified
2128 Planning and quality control engineers	3131 IT operations technicians
2129 Engineering professionals not elsewhere classified	3132 IT user support technicians
2131 IT strategy and planning professionals	3211 Nurses
2132 Software professionals	3212 Midwives
3533 Insurance underwriters	3213 Paramedics
3534 Financial & investment analyst & advisers	3511 Air traffic controllers
3535 Taxation experts	3512 Aircraft pilots and flight engineers
3537 Financial and accounting techs	3513 Ship and hovercraft officers
3568 Environmental health officers	3531 Estimators, valuers and assessors
4121 Credit controllers	3532 Brokers
4122 Accounts wages clerk, bookkeeper	
5242 Telecommunications engineers	
5245 Comp engineer, installation & maintenance	
5249 Electrical & electronic engineer not elsewhere classified	

Source: Deloitte using ONS data

This adjustment (a portion of this occupation for MSR) was based on our understanding of the sector and mathematical science graduates employed in different occupations (see below), a literature review and discussions with a sub-committee of stakeholders and stakeholders at a workshop.

Figure 6.1.2: Occupation of full-time first mathematics and computer science degree leavers entering employment in the UK[52]

Standard Occupational Classification	% Mathematics and Computer Science graduate destination
Managers and senior officials	5%
Professional occupations	10%
Associate professional and technical occupations	4%
Administrative and secretarial occupations	4%
Skilled trades occupations	6%
Personal service occupations	1%
Sales and customer service occupations	5%
Process, plant and machine operatives	6%
Elementary occupations	4%
Not known	3%

Source: HESA

52 The HESA data does not disaggregate between mathematics and computer science graduates. While we acknowledge this is not a perfect measure (and does not include postgraduates) and only captures the flow of new graduates into occupations (rather than the stock of mathematics graduates), it is a reasonable first proxy. Subject research could focus on revising these estimates.

We acknowledge there is an element of subjectivity in these adjustments as data does not readily exist on mathematical science occupations. As this exercise is repeated in the future, we would recommend the collection of further data that will help better inform the number of individuals in mathematical science occupations.

Figure 6.1.3 below presents our rounded estimates of direct employment numbers across each mathematical science occupation, taking into account any adjustments. These percentage adjustments are based on a variety of factors including destinations of mathematical science, our understanding of the stock of mathematics graduates in different occupations, a literature review and discussions with a sub-committee of stakeholders and stakeholders at a workshop.

In some occupations, following the above adjustments the number of individuals in mathematics science occupations was too small to be included for modelling purposes and hence was not included. The level of adjustment ranged from no adjustment to removing the entire occupation category - 17 categories were adjusted.

Figure 6.1.3: Employment numbers in each mathematical science occupation

Level 4 SOC code	Include entire occupation as mathematics occupation?	Apportion needed?	% of category included	Final number of mathematical science occupations	Total number of jobs in SOC category
1111 Senior officials in national government	N	Y	*	400	*
1112 Directors & chief execs of major organisations	N	Y	5%	2,800	60,200
1113 Senior officials in local government	N	Y	5%	1,600	35,100
1121 Prod. works & maintenance managers	N	Y	5%	19,300	413,500
1123 Managers in mining and energy	N	Y	*	12,600	*
1131 Financial managers & chartered secretaries	N	Y	5%	12,100	259,200
1132 Marketing and sales managers	N	Y	5%	25,600	549,400
1133 Purchasing managers	N	Y	5%	2,300	50,100
1136 Information & communication technology managers	Y	N	na	309,900	309,900
1137 Research and development managers	Y	N	na	51,500	51,500
1141 Quality assurance managers	Y	N	na	46,600	46,600
1151 Financial institution managers	N	Y	5%	7,200	154,100
1181 Hospital and health service managers	Y	N	na	77,000	77,000
2111 Chemists	Y	N	na	27,600	27,600
2112 Bio scientists and biochemists	Y	N	na	94,200	94,200
2113 Physicists, geologists & meteorologists	Y	N	na	26,100	26,100
2121 Civil engineers	Y	N	na	78,700	78,700
2122 Mechanical engineers	Y	N	na	78,300	78,300

apportion = divide and allocate

na = not applicable

Level 4 SOC code	Include entire occupation as mathematics occupation?	Apportion needed?	% of category included	Final number of mathematical science occupations	Total number of jobs in SOC category
2123 Electrical engineers	Y	N	na	59,800	59,800
2124 Electronics engineers	Y	N	na	35,900	35,900
2125 Chemical engineers	Y	N	na	9,500	9,500
2126 Design and development engineers	Y	N	na	63,300	63,300
2127 Production and process engineers	Y	N	na	31,200	31,200
2128 Planning and quality control engineers	Y	N	na	29,200	29,200
2129 Engineering professionals not elsewhere classified	Y	N	na	97,100	97,100
2131 IT strategy and planning professionals	Y	N	na	48,900	148,900
2132 Software professionals	Y	N	na	327,500	327,500
2211 Medical practitioners	N	Y	10%	24,200	242,900
2212 Psychologists	N	Y	10%	3,000	29,900
2213 Pharmacists & pharmacologists	Y	N	na	41,800	41,800
2215 Dental practitioners	N	N	na	0	35,700
2311 Higher education teaching professionals	N	Y	10%	13,200	132,600
2317 Registrars & senior administrators of educational establishments	N	Y	10%	4,700	47,200

Level 4 SOC code	Include entire occupation as mathematics occupation?	Apportion needed?	% of category included	Final number of mathematical science occupations	Total number of jobs in SOC category
2321 Scientific researchers	Y	N	na	17,100	17,100
2322 Social science researchers	Y	N	na	17,100	17,100
2329 Researchers not elsewhere classified	Y	N	na	49,100	49,100
2421 Chartered and certified accountants	N	Y	10%	15,900	160,000
2422 Management accountants	Y	N	na	85,700	85,700
2423 Management consultants, actuaries, economists & statisticians	Y	N	na	180,400	180,400
2431 Architects	N	N	na	0	55,400
2432 Town planners	N	Y	10%	2,000	20,700
2433 Quantity surveyors	N	N	0%	0	39,700
2434 Chartered surveyors (not quantity surveyors)	N	N	na	0	63,500
2441 Public service administrative professionals	Y	N	na	34,900	34,900
3111 Laboratory technicians	Y	N	na	64,900	64,900
3112 Electrical & electronic technicians	Y	N	na	26,500	26,500
3113 Engineering technicians	Y	N	na	73,500	73,500
3114 Build & civil eng technicians	Y	N	na	25,800	25,800
3115 Quality assurance technicians	Y	N	na	15,700	15,700

Level 4 SOC code	Include entire occupation as mathematics occupation?	Apportion needed?	% of category included	Final number of mathematical science occupations	Total number of jobs in SOC category
3119 Science & engineering technicians not elsewhere classified	Y	N	na	38,200	38,200
3131 IT operations technicians	N	N	na	0	117,000
3132 IT user support technicians	N	N	na	0	65,400
3211 Nurses	N	N	na	0	509,300
3212 Midwives	N	N	na	0	35,100
3213 Paramedics	N	N	na	0	20,800
3511 Air traffic controllers	Y	N	*	8,900	*
3512 Aircraft pilots and flight engineers	Y	N	na	22,600	22,600
3513 Ship and hovercraft officers	N	N	na	0	15,200
3531 Estimators, valuers and assessors	N	N	na	0	55,300
3532 Brokers	N	Y	0%	0	50,900
3533 Insurance underwriters	Y	N	na	30,100	30,100
3534 Fin. & invest. analyst & advisers	Y	N	na	173,900	173,900
3535 Taxation experts	N	Y	4%	900	21,500
3537 Financial and accounting technicians	N	N	na	0	30,800
3568 Environmental health officers	Y	N	4%	11,900	11,900
4121 Credit controllers	Y	N	4%	45,600	45,600
4122 Accounts wages clerk, bookkeeper	N	N	na	0	512,700

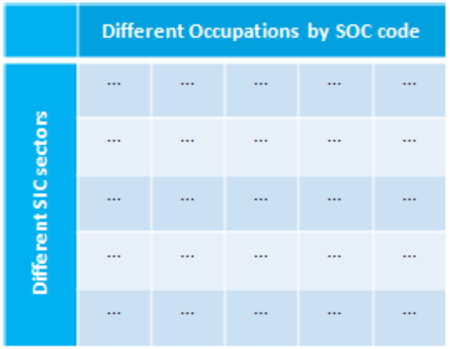
Level 4 SOC code	Include entire occupation as mathematics occupation?	Apportion needed?	% of category included	Final number of mathematical science occupations	Total number of jobs in SOC category
5242 Telecommunications engineers	Y	N	na	42,600	42,600
5245 Comp engineer, installation & maintenance	N	N	na	0	43,500
5249 Electrical & electronics engineer not elsewhere classified	Y	N	na	83,500	83,500

Source: Deloitte using ONS data. Numbers are rounded. * refer to where the underlying data is not available publicly and hence the adjustment percentage cannot be disclosed. Note, numbers do not sum to 2.8 million due to rounding.

Allocating occupations across different sectors of the UK economy in order to calculate GVA

We have used the most detailed sectoral breakdown (4-digit level SIC) which splits the economy into over 600 sectors[53].

Figure 6.2.1: Example SIC-SOC matrix



Thus, the full SIC-SOC matrix is approximately 600x350. Having defined the 70 mathematical science occupations it was then possible to identify levels of employment in each sector of the UK economy. This was done as follows:

⇒ Refer to the original SIC-SOC matrix to understand how each SOC job is distributed across the 600+ SIC sectors and calculate the distribution ratios; and then

⇒ Take the mathematical science occupation SOC codes and the number of jobs in each and distribute them across the 600+ SIC sectors using the distribution ratios calculated above.

This gave us the numbers of mathematical science occupations in each SIC category. However, the UK Domestic Use Matrix (DUM), which forms the basis of our Input-Output model (see below) uses broader categories than the SIC sectors. Rather than 600+ economic sectors, it uses 100+ sectors. Thus, it was necessary to convert the SIC categories into DUM categories. Having made these adjustments, we reached a figure for direct employment attributable to mathematical science research.

[53] This matrix is based on the Annual Population Survey, an annual survey of households undertaken by ONS. As this matrix is extremely detailed (615 rows by 354 columns) compared to the relatively small sample size of the Annual Population Survey, in some instances ONS does not disclose employment information which it deems as unreliable.

Figure 6.2.1: Mathematical science occupations by sector[54]

Sector in model	Number of mathematical science occupation jobs
Agriculture	1,000
Forestry	0
Fishing	0
Coal extraction	1,000
Oil and gas extraction	6,100
Metal ores extraction, Other mining and quarrying	30,000
Meat processing	2,100
Fish and fruit processing	100
Oils and fats processing	0
Dairy products	2,000
Grain milling and starch	0
Animal feed	100
Bread, biscuits, etc	100
Sugar	600
Confectionery	600
Other food products	600
Alcoholic beverages	700
Soft drinks & mineral waters	700
Tobacco products	0
Textile fibres, Textile weaving, Textile finishing	300
Made-up textiles, Carpets and rugs, Other textiles, Knitted goods	0

[54] Due to licence restrictions we are unable to show the total number of jobs in each DUMs sector.

Standard Industrial Classification (SIC) : First introduced in the UK in 1948, this is a framework for classifying business establishments and other statistical units by the type of economic activity in which they are engaged. There are a number of levels of the classification, with subsequent levels becoming more detailed.

Standard Occupational Classification (SOC) : A common classification framework of occupational information for the UK on the basis of skill level and skill content.

Sector in model	Number of mathematical science occupation jobs
Wearing apparel & fur products	200
Leather goods, Footwear	0
Wood and wood products	400
Pulp, paper and paperboard	200
Paper and paperboard products	100
Printing and publishing	14,900
Coke ovens, refined petroleum & nuclear fuel	13,500
Industrial gases and dyes	0
Inorganic chemicals, Organic chemicals	4,600
Fertilisers, Plastics & Synthetic resins etc, Pesticides	0
Paints, varnishes, printing ink etc	1,800
Pharmaceuticals	56,200
Soap and toilet preparations	1,200
Other Chemical products, Man-made fibres	1,400
Rubber products	100
Plastic products	8,200
Glass and glass products	100
Ceramic goods	0
Structural clay products, Cement, lime and plaster	0
Articles of concrete, stone etc	100
Iron and steel, Non-ferrous metals, Metal castings	6,700
Structural metal products	300
Metal boilers & radiators	0
Metal forging, pressing, etc	16,200
Cutlery, tools etc	100
Other Metal products	200
Mechanical power equipment	0
General purpose machinery	6,800

Sector in model	Number of mathematical science occupation jobs
Agricultural machinery	1,000
Machine tools	12,900
Special purpose machinery	1,400
Weapons and ammunition	3,900
Domestic appliances not elsewhere classified	1,200
Office machinery & computers	20,900
Electric motors and generators etc, Insulated wire and cable	2,100
Electrical equipment not elsewhere classified	2,600
Electronic components	10,100
Transmitters for TV, radio and phone	2,500
Receivers for TV and radio	7,400
Medical and precision instruments	28,600
Motor vehicles	29,400
Shipbuilding and repair	4,500
Other transport equipment	3,400
Aircraft and spacecraft	59,600
Furniture	2,700
Jewellery & related products	0
Sports goods and toys	200
Miscellaneous manufacturing not elsewhere classified, recycling	39,000
Electricity production & distribution	30,500
Gas distribution	8,700
Water supply	16,000
Construction	203,800
Motor vehicle distribution & repair, fuel	8,500
Wholesale distribution	15,700
Retail distribution	47,500
Hotels, catering, pubs etc	900

Sector in model	Number of mathematical science occupation jobs
Railway transport	3,000
Other land transport	5,500
Water transport	1,200
Air Transport	17,600
Ancillary Transport services	11,400
Postal and courier services	5,500
Telecommunications	85,900
Banking and finance	156,500
Insurance and pension funds	61,600
Auxiliary financial services	131,400
Owning and dealing in real estate	0
Letting of dwellings	4,700
Estate agent activities	1,500
Renting of machinery etc	3,100
Computer services	346,600
Research and development	81,200
Legal activities	3,700
Accountancy services	48,100
Market research, management consultancy	124,100
Architectural activities & Tech. Consult	214,700
Advertising	8,200
Other business services	66,200
Public administration & defence	257,200
Education	188,700
Health and veterinary services	181,700
Social work activities	20,800
Sewage and Sanitary services	2,000
Membership organisations not elsewhere classified	17,500
Recreational services	10,300
Other service activities	22,900
Total	**2,827,100**

Source: Deloitte using ONS data. Note: variance in numbers is due to rounding.

Having made this conversion, we ran our Input-Output model to calculate direct GVA attributable to MSR as well as supply chain linkages and induced impacts.

⇒ **indirect impact**: changes in the number of jobs and GVA in associated industries that supply inputs to businesses generating and applying mathematical science research (sometimes referred to as 'supply-chain' impacts); and

⇒ **induced impact**: the spending by households that result in changes to the number of jobs and GVA due to direct and indirect impacts.

The process behind constructing an Input-Output model is complex[55] and involves considering the gross revenue earned in each sector and applying adjustments so that it only represents additional revenue as compared to the counterfactual case of there being no mathematical science research. In this instance, it was the case that a detailed counterfactual case was not necessary given that mathematics is so heavily engrained in economic activity. We have then applied multiplier effects in the model to trace the impact across all sectors of the economy.

[55] Broadly speaking, the Domestic Use Matrix (differentiating between domestic purchases and imports) is used to give a matrix of coefficients, detailing the proportion of inputs sourced by an industry from all other industries and labour. The matrix of coefficients is then subtracted from the identity matrix before being inverted to give the *Leontief Inverse*. This matrix then details Type II multipliers for each country, such that a multiplier of, for example, 1.8 in 'mathematics critical sector' means that for a direct impact of £1 million in Gross Revenue terms, a further £0.8 million would be generated by business-to-business purchases in the supply chain and induced consumer spending for a total expenditure (or Gross Output) impact of £1.8 million.