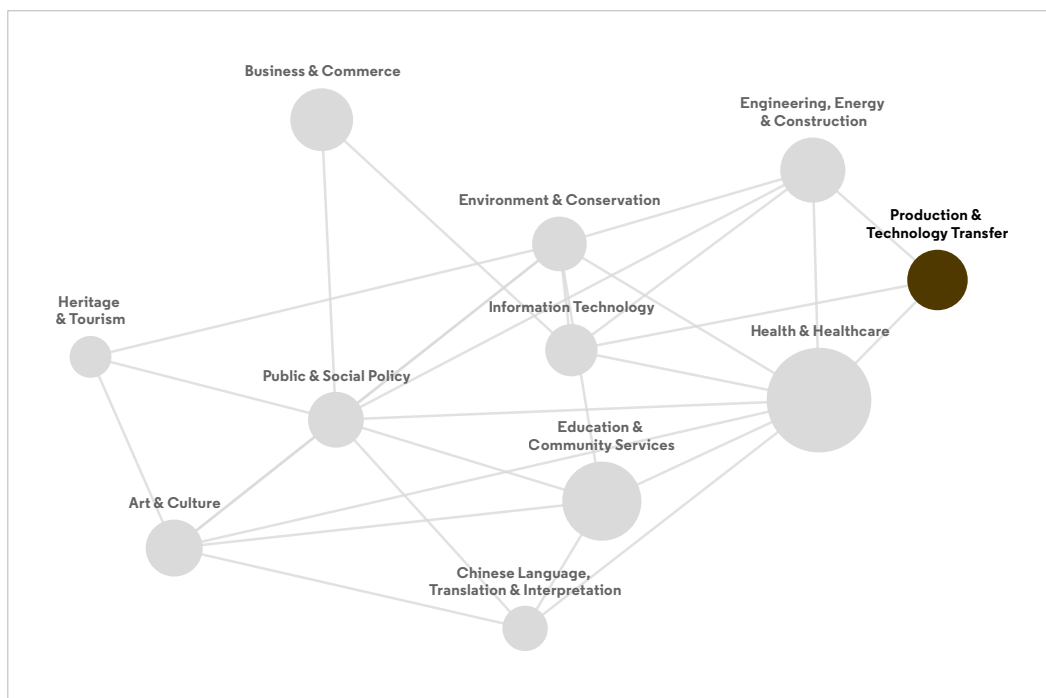




The societal impact of research undertaken by Hong Kong universities:

# Production & Technology Transfer

A synthesis of the RAE 2020 impact case studies



Partnered with:



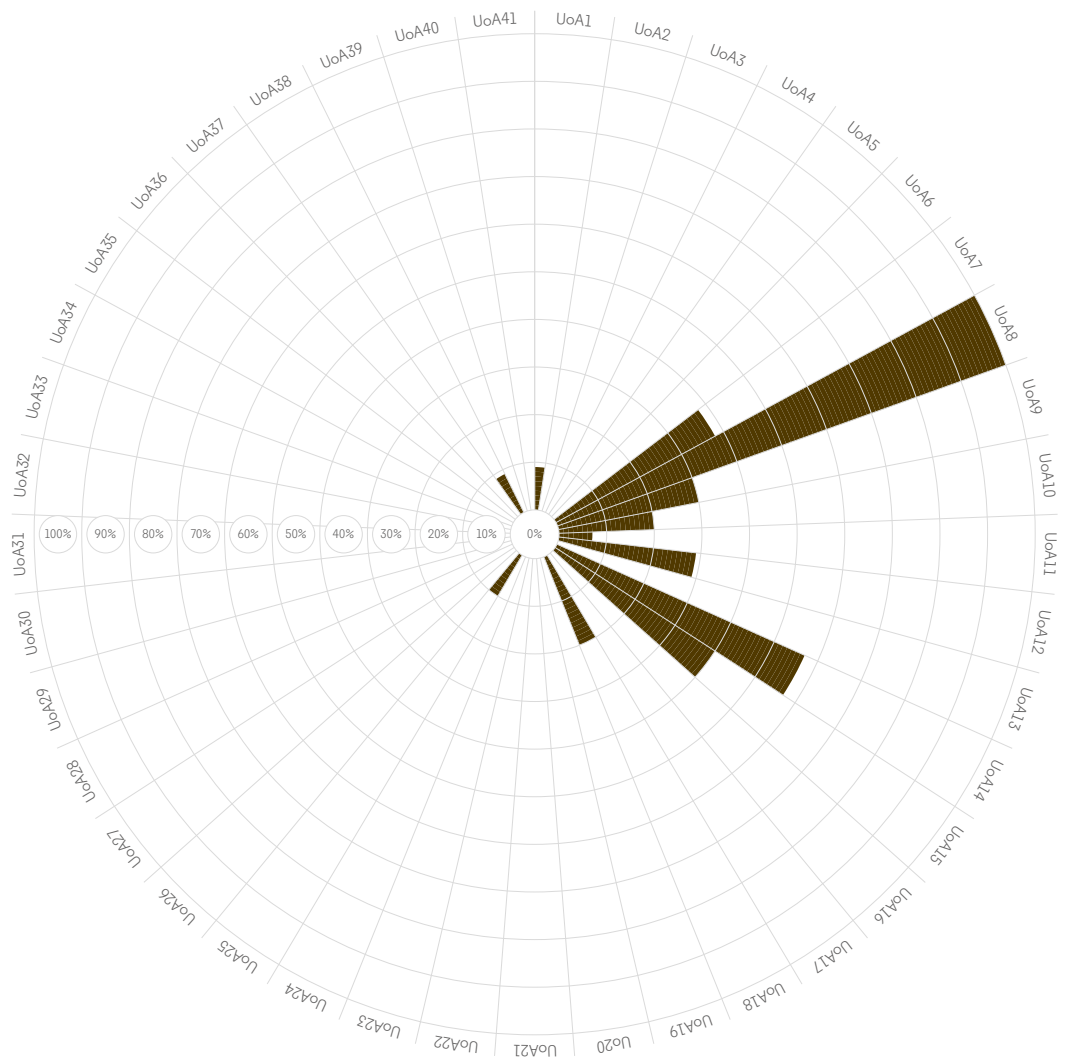
This report is part of a series of outputs that examines the impact of research arising from eight universities based in Hong Kong and funded by the University Grants Committee (UGC). The report focuses on the Impact Case Studies (ICS) produced by the UGC-funded universities as part of their response to a Research Assessment Exercise (RAE) in 2020. The overarching report - *The impact of research undertaken by universities in Hong Kong: A synthesis of the RAE 2020 impact case studies* – is accompanied by 11 thematic reports that examine the nature of research impact in different areas, ranging from Arts & Culture to Health & Healthcare. The 342 impact case studies that are analysed through this body of work are also available on a searchable database that is posted on the UGC’s website.

**The Production & Technology Transfer cluster contains 30 impact case studies from two primary topics identified in the topic modelling.<sup>1</sup> The cluster represents 9% (i.e. 30/342) of the case studies submitted to RAE 2020.**

The impact wheel in Figure 1 illustrates how the Production & Technology Transfer cluster is distributed across the 41 Units of Assessment (UoAs) used for RAE 2020. For example, for UoA 8 (materials science and materials technology), all four of the ICS (i.e. 100%) submitted to the UoA were in the Production & Technology Transfer cluster.

Overall 12 of the 41 UoA contributed to this cluster with the remaining eleven UoAs including: UoA 1 (biological sciences); UoA 7 (physics & astronomy); UoA 9 (chemistry); UoA 10 (earth sciences and other physical sciences); UoA 11 (mathematics and statistics); UoA 12 (electrical & electronic engineering); UoA 14 (mechanical engineering, production engineering, textile technology and aerospace engineering); UoA 15 (chemical engineering, biomedical engineering, other technologies and marine engineering); UoA 18 (planning and surveying); UoA 25 (political science); and UoA 38 (visual arts, design, creative media, other creative arts and creative writing).

**Figure 1:** Impact wheel for the Production & Technology Transfer cluster (n=30)



<sup>1</sup> See methodological annex for details.

# The impact of Hong Kong universities' research: **Production & Technology Transfer**

**Table A shows the most salient features of the case studies in terms of beneficiaries, location, type of impact and time lag. It gives the percentage of case studies in this cluster that were tagged with sub-codes under these code headings, as well as the percentage of case studies tagged with those sub-codes in the entire sample of 342.**

The 30 case studies in this cluster impacted beneficiaries in three key sectors under the classification of the Hong Kong Standard Industrial Classification: 50% benefited the Manufacturing sector, 43% Import/export, wholesale and retail and 27% Information and communications. The key socioeconomic groups mentioned in the ICS were patient groups (17%), citizens and communities (10%) and disabled people (10%). The primary decision taker groups that were involved in the impact were the private sector (67%) and government departments/agencies (17%). Beyond Hong Kong (43%),

the Greater Bay Area (10%) and Mainland China (43%), these case studies primarily had an impact in the United States (50%) and Japan (20%). The most salient types of impact were commercialisation of new technology (70%) and generating profit or revenue (70%). This was followed by investment received from industry (60%) and service or product in regular use (60%). On average, the research in this cluster was started in 2006, which is the same as for the whole sample. The median publication date for this cluster was 2014, compared to the publication date of 2015 for the whole sample.

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On reading the ICS in the Production & Technology Transfer cluster it was evident that the majority of ICS could be grouped into three main subthemes: electronics, medicine and food, and textiles.

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**Table A:** Some salient features of research impact identified in the Production & Technology Transfer cluster (n=30)

<b>Beneficiaries of impact (top mentions)</b>	<b>% of <u>cluster</u> impact case studies</b>	<b>% of <u>all</u> impact case studies</b>
<b>Hong Kong Standard Industrial Classification</b>		
Manufacturing	50%	9%
Import/export, wholesale and retail	43%	8%
Information and communications	27%	11%
<b>Sociodemographic group</b>		
Patient groups	17%	12%
Citizens/communities	10%	17%
Disabled People	10%	4%
<b>Decision taker group</b>		
Private sector	67%	30%
Government departments/agencies	17%	31%
<b>Location of impact</b>		
	<b>% of <u>cluster</u> impact case studies</b>	<b>% of <u>all</u> impact case studies</b>
Hong Kong	43%	75%
Greater Bay Area (excluding Hong Kong)	10%	3%
Mainland China (excluding Hong Kong and GBA)	43%	12%
United States	50%	32%
Japan	20%	11%
<b>Type of impact (top mentions)</b>		
	<b>% of <u>cluster</u> impact case studies</b>	<b>% of <u>all</u> impact case studies</b>
Commercialise new technology	70%	15%
Generate profit/revenue or cost savings	70%	18%
Investment received from industry	60%	15%
Service or product in regular use	60%	28%
<b>Elapsed time</b>		
	<b><u>Cluster</u></b>	<b><u>All</u></b>
Median year of research commencement	2006	2006
Median year of publication date	2014	2015

## Electronics

One area of impact arising relates to electronics. One highly impactful ICS details research by City University of Hong Kong, which developed a computerized 3D camera for real-time acquisition and processing of 3D objects. Former PhD students developed this work and created a spin-off company Orbbec Co. Ltd, which has become a leading provider of 3D sensing solutions. Headquartered in Shenzhen, the company has over 300 employees, generates annual revenue of US\$100 million and is valued at over US\$1 billion. Another interesting ICS from The Hong Kong Polytechnic University showcases research on planetary remote sensing, which has application for landing site characterization and selection. This work has been taken up by China's space exploration missions, providing a 3D mapping model for high-precision and high-resolution topographic mapping of the Moon and Mars and allowing for vast improvements in landing site evaluation, descent orbit design, and surface operation. Another ICS describes how researchers at City University of Hong Kong developed an intelligent sensor system which is used for the roughly 260 million passengers who pass through the immigration gates in Hong Kong. The sensor is used at the HK immigration gates, which has been generating a yearly revenue of more than HK\$10m (cUS\$1.3m) since 2013.

Another ICS describes how researchers at The Chinese University of Hong Kong created flexible, lightweight and stable CIGS solar cells and modules with internationally competitive energy conversion efficiency and world-leading module dimensions. This led to 56 patents and a start-up company, Shinetech, with 60 employees producing 5W rollable solar chargers and 24W flexible charging stations, generating RMB2.4M (cUS\$0.36) annually. In another ICS, also from The Chinese University of Hong Kong, researchers formulated new white ink in digit printing, which has low sedimentation and high white opacity. This has been widely sold to electronic industries, including Lenovo, and has gained investment from leading chemical company BASF for developing sunscreen and daily cosmetic products. A third ICS gives detail on a new transparent barrier that protects gold-plating on watches from oxidation or corrosion, which was developed

by researchers at City University of Hong Kong. Another example of impact comes from patents for OLED display technology (i.e. electronic visual panels) developed by researchers at The University of Hong Kong. This technology was exclusively licensed to major global OLED display manufacturers, including Samsung, Merck, and Aglaia. The research has attracted industrial capital and led to a joint laboratory with TCL Corporation, one of China's largest enterprises, to develop printable OLED materials. Another ICS relates to The Hong Kong Polytechnic University's work on flexible electronics. This technology led to a high-tech spin-off company AdvanPro making mobile-connected wearable monitoring systems for healthcare and sports in China. This created 60 new jobs, sold over 32,000 products, and has generated approximately HK\$22.4m (cUS\$2.8m) in total sales. In a related ICS researchers at The University of Hong Kong created new sensors in smartwatches for health monitoring in collaboration with Huawei. One spin off company arising from this technology has received investment of over HK\$80m (cUS\$10.2m).

There were another group of ICS related to technology behind other electronic innovations. For example, researchers from The Hong Kong Polytechnic University developed optical components and signal processing algorithms, which have helped Huawei define technology standards for data centre transmissions and improved Huawei's optical transceiver testing chipset. The research also led to a spin-off a start-up company that specialises in fibre amplifiers and associated equipment. Similarly, another ICS details innovations in antennas for modern wireless communications by researchers at City University of Hong Kong. These innovations led to the establishment of a joint venture in Shandong Province that produces novel wideband base station antennas that have been widely used in the country; a spin off company that develops novel small antenna for the BeiDou Navigation Satellite System of China; and new antenna technology for 5G and 6G. A third example relates research at The Hong Kong University of Science and Technology on motion and robot control. The technologies developed provide motion controllers with better accuracy, faster response, and higher efficiency, and have been commercialised through a start-up

company Googol Technology Ltd. Another ICS describes motion capture and assistive devices/systems research by scientists at City University of Hong Kong. This research was commercialised through a start-up company, which has led to the use of novel technology worldwide in filmmaking (special effects), animation and game interaction, sports training, and medical rehabilitation. Remarkably, the users of the developed products/technologies include Emmy Award winning 'Game of Thrones', 60% of US PGA top 100 coaches, and NASA for the commemoration of the 50th Anniversary of Human Landing on Moon. Another interesting example is work on motion tracking and recognition by researchers from City University of Hong Kong, which led to the successful commercialisation of products that merged motion sensing and artificial intelligence technologies. This led to several companies, which employ around 100 employees total and have gained funding from international venture capital and generated substantial sales income.

## Medicine and food

One very interesting area of impact relates to the development of medical devices and technology. For example, one ICS showcases research from The Hong Kong Polytechnic University in collaboration with the Shantou Institute of Ultrasonic Instruments Co. Ltd, which significantly improved medical imaging devices, helped develop three new products, and delivered training to boost the company's R&D capabilities. These products have generated combined sales of over HK\$20m (cUS\$2.5m). Another ICS highlights the development of a cheap and reliable histamine detector based on research by City University of Hong Kong that can lead to substantial reductions in severe dietary reactions, such as asthma and hypotension. This has generated funding worth RMB20m (cUS\$3m) from government and industry, and a company "XMinnov Limited" employs 10 full time staff for commercialization, and

the technology is being used by Xiamen Entry-Exit Inspection and Quarantine Bureau for pre-screening of histamine in food. A third ICS describes breakthrough facemask technology developed by researchers from The Hong Kong Polytechnic University using multi-layers of nanofibers separated by permeable substrate. A start-up company, A Avalon Nanofiber Ltd. Taipei, gained a total investment of HK\$30m (cUS\$3.8m), employs 10 professionals, and has sold over two million facemasks. This has greatly benefitted people with respiratory diseases, compromised immune systems, and pollen allergies.

A further group of ICS relate to medical technology. One details the development of robust methods for the synthesis of different noble metal nanocrystals by researchers from The Chinese University of Hong Kong, which has been employed by three spin-out companies. This technology has reached over 1,000 customers in more than 30 countries and regions and has been used in R&D in medicine, diagnostics, biotechnologies, optical and optoelectronic devices, in detection methods for monitoring the quality and safety of foods, beverages, drugs and explosives. A second ICS, from City University of Hong Kong, details ultrasound-based non-contact motion sensors and biopotential sensing technology for disease diagnosis, ambulatory monitoring, and rehabilitation. This has been used for applications such as surgery assistance and interactive modules in public and commercial exhibition platforms. The third showcases ground-breaking indelible ink developed by researchers from The Hong Kong Polytechnic University that has led to large scale economic, industry and food safety impacts. A spin-off company Xianhong provides tamper-proof expiry dates and product information for some of China's biggest food and beverage manufacturers, employs over 60 staff, and has annual sales of over RMB150m (cUS\$22m). Further evidence of the impact of this innovation is its use by three of the top dairies in the world (Nestle, Yili, Mengniu), and sales covering 14% of the Chinese fast-moving goods industry.

Two ICS related to food. In the first of these, researchers at City University of Hong Kong developed a composite material based on a by-product from the sugarcane industry, designed to replace environmentally damaging plastic food packaging material. This product has been demonstrated to be gas-, heat-, oil- resistant, and 100% biodegradable. Over HK\$5m (cUS\$0.64m) has been invested from government and industry, and a start-up company, Ecoinno Limited, has been developed, which employs 12 full-time staff. In the second, researchers from The Hong Kong University of Science and Technology have spearheaded the development and use of natural compounds, such as edible bird's nest, Chinese herbs, and various bacteria. For example, developments in the identification, authentication, and extraction of active ingredients in edible bird's nest led to a highly successful range of skincare products. This work has led to health and well-being benefits for consumers.

## Textiles

Another area of impact focuses on technologies around textile products and manufacturing. One interesting example is research at The Hong Kong Polytechnic University. Researchers developed a Moisture Management Tester, which provides the basis for international standards on 'wicking' fabrics. Having sold over 250 units, this instrument aids innovation in a US\$2.6 billion global market. Another instrument, the Fabric Touch Tester, is an affordable objective measure of hand-

feel, which has been sold in 16 countries and supports global clothing companies' R&D and quality control. Another example is research also at The Hong Kong Polytechnic University but this time on metal-coated textiles with unique visual effects. Two new companies have been created, over 20 fashion designers have used the textiles in their work and the anti-bacterial, UV and heat-shielding qualities have been used in an elderly residential home. A third ICS showcases a new market-leading yarn spinning technology, 'Nu-Torque', which solved a long-standing industry problem preventing high-quality high-strength yarn production. The technology has been licensed by 10 manufacturers, including some of the world's largest cotton manufacturers, and it has been used in products for Armani and UNIQLO. One company deploying Nu-Torque products generated HK\$236m (cUS\$30m) in profit. Another provides details of how researchers from The Hong Kong Polytechnic University developed a hybrid statistical model that reduces production costs and fabric wastage. Used by Esquel, a global textile manufacturer based in China, over HK\$2.5m (cUS\$0.3m) has been saved in production costs, as well as a reduction of 120,000 yards annually plus a 375-ton reduction in greenhouse gases. A final ICS – from The Hong Kong University of Science and Technology - describes research into an innovation-based "third dimension" that has led to Hong Kong-owned underwear plant in Guangdong changing its business model to focus on higher value output, saving jobs in the province, informed thousands of factory owners about the merits of staying in situ; contributed to the on-going global discussion of China's innovation leadership.



# The characteristics and translation of the underpinning research

**Table B provides the salient features of the underpinning research. It provides bibliometrics as well as information on the impetus for the research and mechanisms/channels of dissemination.**

131 outputs from this cluster are indexed on the Web of Science, which have a mean citation score of 2.25. The median citation score is 1.59, which is equal to the median of 1.59 for all case studies. Key international collaborators included the United States (9%), the UK (2%), and Germany (2%). 50% of the research was in response to demand for better innovation and technology and 10% was commissioned.

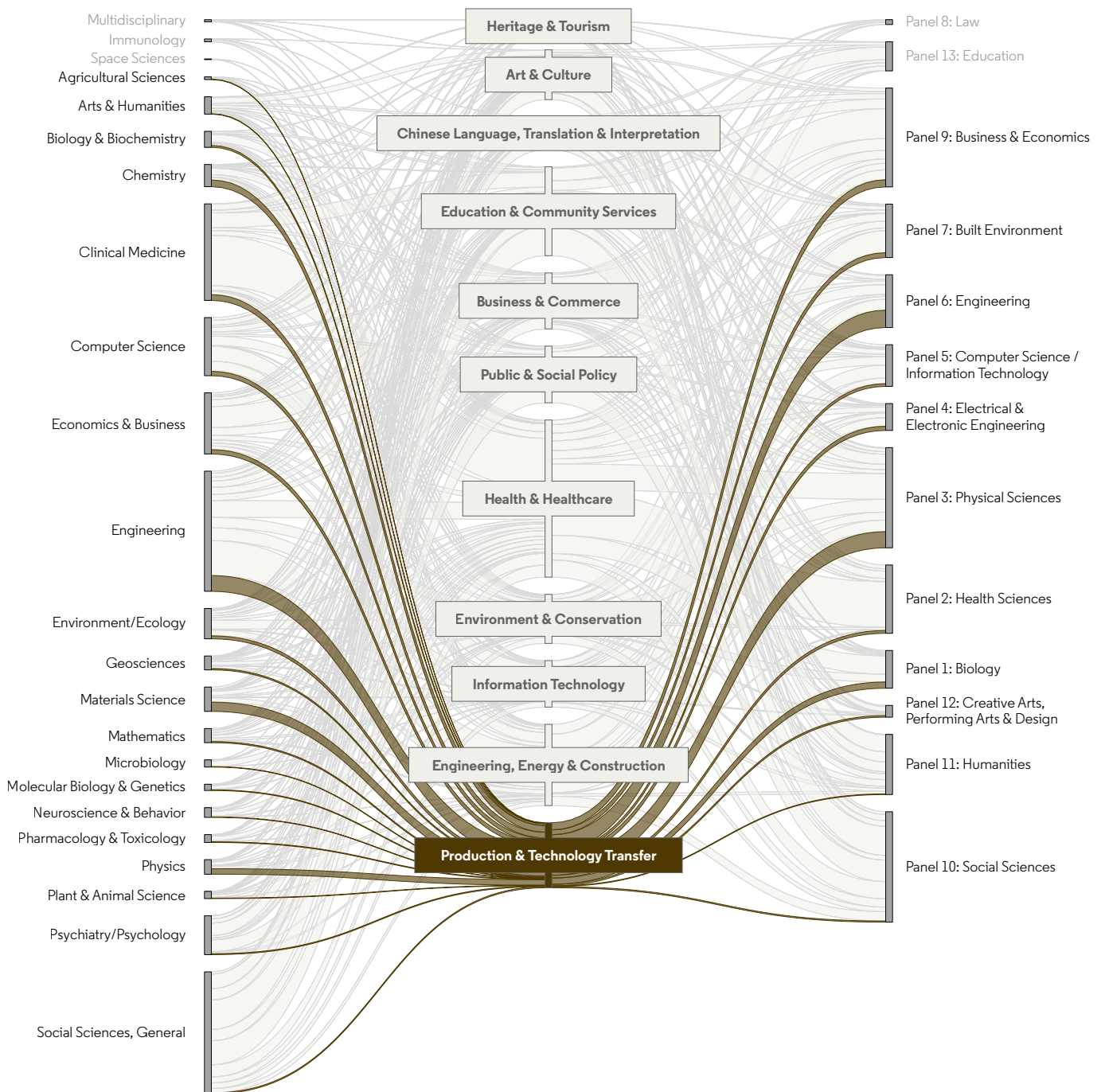
The research sometimes followed on from previous work (3%). The main forms of co-production and collaboration were academic and industry partnership (60%) and academic and third sector partnership (10%). The researcher was involved in the impact through being referenced as expert, practitioner, or advisor in 40% of cases, or co-produced new technology or product (20%). The research findings were disseminated primarily through media coverage (37%) and through non-academic presentations (17%). Many ideas and products arising from the research were given prizes and awards (60%) and some were formally recommended by recognised bodies (10%).

**Table B:** Some salient features of the underpinning research identified in the Production & Technology Transfer cluster (n = 30)

<b>Analysis of underpinning research</b>	<b><u>Cluster</u> impact case studies</b>	<b><u>All</u> impact case studies</b>
<b>Bibliometrics indicators</b>		
Number of outputs indexed on Web of Science	131	1445
Mean citation score	2.25	4.45
Median citation score	1.59	1.59
<b>Collaborators location (top mentions, excluding China)</b>		
USA	9%	18%
UK	2%	8%
Germany	2%	2%
<b>Impetus for research (top two mentions)</b>	<b>% of <u>cluster</u> impact case studies</b>	<b>% of <u>all</u> impact case studies</b>
<b>Pull factors</b>		
Demand for better innovation & technology	50%	11%
Commissioned	10%	16%
<b>Push factors</b>		
Follow on from research team's previous work	3%	12%
<b>Mechanisms/channels of impact (top mentions)</b>	<b>% of <u>cluster</u> impact case studies</b>	<b>% of <u>all</u> impact case studies</b>
<b>Coproduction &amp; collaboration</b>		
Academic - industry partnership	60%	23%
Academic - third sector partnership	10%	8%
<b>Researcher involvement</b>		
Referenced as expert, practitioner or adviser	40%	33%
Co-produced new technology/product	20%	9%
<b>Dissemination of research findings</b>		
Media coverage	37%	48%
Non-academic presentation (incl public lecture)	17%	36%
<b>Codification of impact eg prizes, patents etc.</b>		
Prizes and awards	60%	33%
Idea/product/invention formally recommended by recognised body	10%	12%

The alluvial diagram in Figure 2 links the underpinning research (as classified by discipline using the 23 Web of Science, Essential Science Indicators (ESI), journal categories) to the 11 clusters identified through the topic modelling and the 13 Panels used in RAE 2020. The Production & Technology Transfer cluster has been highlighted, with the impact pathways for the other clusters greyed out. Figure 2 illustrates the multidisciplinary nature of research impact; multiple journal categories feed into the cluster and the cluster contributes to ICS submitted to a range of RAE panels.

**Figure 2:** Alluvial diagram linking underpinning research with clusters and panels.



# Methodological annex

This synthesised impact report presents a cross-cases analysis of the salient features in 342 impact case studies (ICS) provided by Hong Kong universities as part of the RAE 2020 evaluation. A sequential multi-method approach was employed. The first component involved quantitative topic modelling, followed by directed content analysis. This approach allowed the essence of the impact generated by Hong Kong universities to be captured and synthesised. It is important to note that the analysis and conclusions of these reports are based on the impact as described in the ICS. That is, the authors of this report took the case studies at face value and did not verify or question the narratives provided. A summary of the methodology is given below. For more detailed information on the methodological elements of this study, please see the overarching impact report.

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## Quantitative topic modelling

Quantitative topic modelling was used to identify overarching topics in the ICS. Topic modelling is a language processing technique applied to document sets to understand the different combinations of words or phrases (topics) that are present. It is a data driven approach, meaning results are not dependent on pre-conceived notions of structure, but are instead derived from the data itself.

Python, Scikit Learn, and Gensim packages were used to implement the topic modelling. Text from section 4 (Details of Impact) from the ICS was normalized (i.e. removal of punctuation and special characters), and domain specific stop-words were removed (i.e. words that are used frequently across the case studies). Various implementations of

the topic modelling algorithm were tested, and the Non-negative matrix factorization [NMF] was found to produce the most usable results. After testing multiple models using this algorithm, and manual review by the authors, the number of topics was set to 35 to provide a balance between the breadth of groupings and granularity of topics.

In discussion with UGC, the research team developed an initial taxonomy by grouping similar topics into broader 'clusters'. For example, the topics 'finance', 'accountancy and governance', and 'economics' were grouped into a cluster titled 'business & commerce'. Topic clusters were set at the outset of the analysis to ensure cognitively similar cases were read together, thereby improving the quality of coding, analysis, and impact reports. This classification system then informed the coding and testing of case studies.

## Directed content analysis

Qualitative directed content analysis was then used to elucidate the salient characteristics of the impact narratives. This involved an iterative process of examining case studies and developing a code book to categorise their inherent features. The code book was derived from the existing literature and the domain expertise of the authors. It included four overarching categories: a) research, which captured funding source and impetus for research; b) time lags, which captured the elapsed time between the research and its impact; c) mechanisms/channels of impact, which included forms of collaboration and dissemination; and d) impact, which included beneficiary groups (e.g. young people, women, ethnic minorities), location and reach (e.g. Hong Kong, Mainland China, elsewhere), and the nature of impact (e.g. commercial, policy, practice).

Using the cloud based qualitative analysis software, Dedoose, each case study was read, and relevant excerpts were 'tagged' with the relevant codes. Multiple codes

and subcodes were attributed to individual case studies. This allowed all case studies that had been tagged with a particular code (e.g. a particular beneficiary group) to be considered as a group. Two of the study's authors undertook the reading and coding (JG and KW). Inter coder reliability was ensured by double coding 10% of the cases (i.e. each author codes the same case study) and through regular coding meetings that were used to compare code applications and adjust the code book as required. The code book was thus a 'living document' that was reviewed and revised iteratively. This process allowed for cross case analysis that was the basis of synthesised impact reports. A code co-occurrence matrix was used to identify where the overarching codes intersect (for example, instances where particular topics are associated with particular beneficiary groups). The properties of the ICS were systematically examined, and evidence was gathered by assigning segments of text to unique codes within the broader coding categories. This process allowed for cross case analysis that formed the basis of this synthesised impact report.

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Different Angles Ltd is a consultancy with a distinctive focus on the social impact of universities and research. Founded by Jonathan Grant in 2020, Different Angles provides consultancy, evaluation and training to individuals and institutions in the UK and across the globe. Different Angles clients are a diverse mix of research funders, universities and private innovators & philanthropists. We aim to help clients co-create and co-design innovative, impactful and influential interventions.

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