Final Report
14 September 2023

Understanding Northern Ireland's Software Capability and Future 'Windows of Opportunity'

steer economic development

DMS RESEARCH & CONSULTING

DfE NI

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Understanding Northern Ireland's Software Capability and Future 'Windows of Opportunity'

Prepared by:

Steer Economic Development
and DMS Research & Consulting
61 Mosley Street
Manchester M2 3HZ

+44 161 261 9141
www.steer-ed.com

Prepared for:

Department for the Economy
Adelaide House
39-49 Adelaide Street
Belfast, BT2 8FD
Northern Ireland

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Contents

Figures

Tables

Annexes

Executive Summary

In January 2023, the Department for the Economy (DfE) commissioned Steer Economic Development (Steer-ED), supported by DMS Research & Consulting and Norman Apsley, to undertake research into Northern Ireland's software economy: the organisations and people that develop, implement and support software-based functionality, products and services. This is the study's Final Report.

NI's Software Economy – Key Facts

- There are c. 46,000 people employed in NI's software economy, including 16,500 in software SICs and 38,300 in software SOCs
- There is currently a major gender imbalance, however: women account for just 27% of employees in software industries, and only 17% of NI residents in software occupations
- Belfast accounts for 40% of NI's total business sites in the software-related SICs (compared with its 18% population share), and is dominant in terms of the sites which have 10 or more employees
- NI's software industries generated about £915 million in Gross Value Added (GVA) in 2021, having grown in real terms at an average of 12% p.a. since 1998
- The software sector is one of NI's best-paying industries: the median annual pay per employee in SIC 62 (Computer programming, consultancy and related activities) is 52% more than the overall NI earnings median
- In terms of skills supply, there are about 5,000 students enrolled on Computing courses at NI HEIs. Normalised for population size, NI's ratio of Computing students is somewhat higher than the UK average, but is behind that for Scotland and London. Participation in computing education at school is very low in NI; for example, Computing's share of A-level subjects sat is nearly twice as high in England.

Software Technology/Specialisms in NI - Strengths and Needs

- SIC 6201 (Computer programming activities) is an area in which NI has a genuine and significant specialisation
- NI has done well in developing and attracting larger business sites in the field of software development, but is considerably underweight in terms of the presence of micro businesses in software-related areas
- The share of total employment in software-related occupations is rather lower in NI than it is in GB excluding London, but NI has a relative specialism in SOC 2134 (Programmers and software development professionals)
- Analysis of technologies mentioned on LinkedIn and Adzuna suggests that NI is particularly strong in core software engineering technologies such as C#, Java and JavaScript. However, mentions of AI, Machine Learning and Data Science look relatively low, and employment in these areas may be growing more rapidly elsewhere in the UK than they are in NI
- Applying textual analysis and a k-means clustering technique to text scraped from software-intensive companies' websites, we see that the strongest areas of specialism in NI are FinTech, Digital Transformation, Cyber, Data Analytics, and Sensing, Control & Automation

Research and Innovation - Capacities and Capabilities

- There was total R&D expenditure of £210 million in NI's Information and Communications industries in 2019/20, amounting to 26% of all NI expenditure in HMRC's R&D tax credit dataset: a higher proportion than any other nation or region
- Numerous examples of innovation within NI's software-intensive businesses are complemented by a strong academic base. Ulster University ranked 9th out of 90 in REF 2021 for Research Power in Computer Science & Informatics, and 96% of Queen's University Belfast's Engineering submission for REF 2021 was judged to be world-leading or internationally excellent
- In an analysis of Computer Science-related journal articles involving authors from QUB and UU since 2003, Artificial Intelligence, Security and Telecommunications stand out as the areas with the highest impact, and these are areas in which the universities are generally acknowledged to be particularly strong
- Both QUB and UU have spun-out successful software-related companies over the last few decades, most notably Kainos
- Examples of HEI-business collaboration include the universities' business support and incubator/accelerator programmes, Knowledge Transfer Partnerships, interactions on students' PhDs, industry sponsorship of post-docs, businesses using specialist equipment at university facilities, collaborative R&D projects, the AI Research Centre at UU and the forthcoming Cyber-AI Hub to be hosted at QUB
- Some businesses are actively collaborating in research with one or both of the universities and are complementary of their value, while others have had little recent interaction and don't see the research being undertaken at the universities as having particular relevance for them. In general, it appears that smaller businesses are finding harder to engage with the universities than is the case for larger businesses
- QUB's leading position in cyber research has contributed to developing a strong cyber sub-cluster within NI including many FDI firms. Both universities have strengths in Artificial Intelligence, which has a wide range of applicability across the software sector, including the strong areas of the business base in FinTech, Digital Transformation, Data Analytics, Cyber, and Sensing, Control & Automation

Assessment of Growth Prospects and 'Windows of Opportunity'

- The study's review of industry reports and the stakeholder consultations indicate that there continues to be very healthy growth prospects for the areas in which NI is particularly strong: FinTech, Digital Transformation and Cyber
- However, the research also highlights three 'megatrends' which are seen as being critically important throughout NI's software sector, but which are also areas where NI needs to grow its capacity and capabilities to remain globally competitive:
  - Artificial intelligence;
  - Data science and data engineering; and
  - Cloud.
- NI has a 'window of opportunity' over the next five years or so to strengthen its capabilities in these areas. If it fails to do so, there is a real risk of falling further behind competing locations, with adverse consequences for the growth of NI's software economy

Assessment of Software Cluster Characteristics and Key Issues

- The software sector in NI demonstrates several features of a well-functioning industrial cluster. In particular, it benefits from: a highly skilled workforce; strong personal networks

which are reinforced through a healthy meetup scene and various industry conferences; a strong academic base; areas of specialism, particularly in FinTech, Digital Transformation and Cyber; and agglomeration benefits in Belfast
- The recent launch of the Software Alliance is widely seen as being a very positive development – bringing together NI's software-intensive businesses to collaborate on issues of mutual interest, and providing a more coherent 'voice' for the sector
- However, the limited availability of skilled people is holding back the cluster's further development. The strongest message emerging from this study's consultations was that there is an urgent need to tackle the constrained supply of skills into the industry – both in terms of training up local people, and in attracting in talent from elsewhere. If government and the public sector does nothing else for the software sector, it should make concerted efforts, with education providers and industry, to tackle this – difficult – skills supply challenge
- Software-intensive businesses are at the forefront of remote/hybrid working. Managing this effectively, to maximise the benefits while mitigating the potential downsides, has become a critical management competence
- Most consultees suggested that the public sector should avoid trying to 'pick winners' in terms of specific sub-sectors for support. Value is being created across the software sector, including in smaller but emerging areas as well as the more established areas
- However, there is a case for prioritising the development of capabilities in General Purpose Technologies and disciplines that are clearly going to be increasing important in the future and which will be needed and applied throughout the software economy; specifically, the closely linked areas of Artificial Intelligence, Data Science, Data Engineering and Cloud
- There is a need for more focus on supporting indigenous software businesses, in terms of start-up and scale-up: providing a balance to the inward investments that have been so successful in helping to build up NI's software sector, and offering a broader range of job opportunities

Assessment versus 10X Priorities

- The software sector invests heavily in R&D and is an innovation-intensive industry. There are, however, some factors which constrain its innovative potential including being relatively underweight in micro-businesses, difficulties in recruiting for PhDs and post-docs in the areas of AI and data science, under-representation of women in the workforce, and the limited scope of roles offered within NI in some FDI operations
- Although it is not a major area of specialism within NI's software sector, there are various NI businesses developing software to help reduce waste and carbon emissions. The ongoing shift to the cloud is important in improving the sustainability of the industry
- Of the three 10X priorities, NI's software economy is arguably weakest when it comes to the 'Inclusive' priority. In particular the participation of females is chronically low. If 10X is to achieve its objective to 'create opportunities for economic growth which are distributed across society to benefit everyone' then the current inequities in access to computing education will need to be addressed, and more concerted and effective efforts will need to be made to get more girls interested in coding and to encourage women into software occupations.

Recommendations

The study offers 11 recommendations to help enable NI's software economy realise its potential, grouped under four strategic themes:

- **Growing capacity and capability in key technologies:**
  - *Recommendation 1*: DfE should seek to strengthen NI's position in the widely-applicable technology competences of AI, data science, data engineering and cloud, rather than focusing support toward specific narrowly-defined software sub-sectors.
  - *Recommendation 2*: DfE should boost the funding available for PhDs and post-docs in software-intensive disciplines, especially in AI, data science and data engineering.
- **People**:
  - *Recommendation 3*: DfE and the Department of Education (DE) should jointly research global best practice in computing education from primary through to tertiary levels, assess the applicability of initiatives/policies to the NI context, and implement pilots of the most promising approaches.
  - *Recommendation 4*: DE should set out an ambition for all NI's primary and post-primary schools to equip their students with computational thinking and coding skills, and develop a strategy and timescale for achieving this, in liaison with CCEA, ETI, schools, DfE, the universities and industry.
  - *Recommendation 5*: With the universities, the FE sector and industry partners, DfE should seek to substantially grow the numbers of people obtaining Computing-related skills and qualifications, through a variety of pathways, at a pace which matches the growth of NI's software economy.
  - *Recommendation 6*: DfE and Invest NI should take advantage of recent economic and working practice developments to facilitate an increase in the flow of experienced technical and commercial software talent re-locating to NI from GB, RoI and further afield.
  - *Recommendation 7*: The Software Alliance should promote the importance of the sector to the economy by: i) continuing to stress the need for policy clarity, direction and action for the software sector, and ii) considering how best to communicate the opportunities offered by the software sector to key target audiences.
- **Remote working:**
  - *Recommendation 8*: With partners such as the Software Alliance, Digital DNA, Ormeau Baths, Catalyst and others, DfE should seek to ensure that NI's remote tech workers are, and remain, well-connected into the local software ecosystem in NI.
  - *Recommendation 9*: DfE and Invest NI should facilitate the spread of best practice in remote working approaches across the software sector.
- **Pipeline of indigenous start-ups/scale-ups**:
  - *Recommendation 10*: Supported by DfE and industry, QUB and UU should embed entrepreneurship and management education alongside relevant subject areas for the software sector, and facilitate 'collision' opportunities between potential future co-founders.
  - *Recommendation 11*: DfE and Invest NI should put renewed emphasis on support for entrepreneurship and indigenous start-ups and scale-ups in software-intensive activities.

1 Introduction and Methodology

Introduction

1.1 In January 2023, the Department for the Economy (DfE) commissioned **Steer Economic Development (Steer-ED),** supported by **DMS Research & Consulting** and **Norman Apsley**, to undertake research into Northern Ireland's software economy[1]: the organisations and people that develop, implement and support software-based functionality, products and services.

1.2 This is the study's Final Report. It is structured as follows:

- Section 2 provides a brief profile of the software economy in Northern Ireland (NI);
- Section 3 sets out the study's analysis of the areas of specialism and of need in NI's business base;
- Section 4 identifies relevant research and innovation capabilities;
- Section 5 provides an assessment of growth prospects and 'Windows of Opportunity';
- Section 6 assesses the cluster characteristics of NI's software economy, and summarises the key issues faced by the sector;
- Section 7 provides examples of how the sector contributes to the three 10X priorities: innovative, sustainable and inclusive; and
- Section 8 presents the study's overall recommendations.

1.3 There are three supporting annexes:

- Annex A lists the SIC and SOC codes considered to be in-scope for the software economy
- Annex B lists the stakeholders consulted in the course of the study
- Annex C contains a set of charts resulting from the study's clustering analysis of software-intensive companies, based on companies' website text.

Methodology

1.4 The research approach is illustrated in the figure below.

Figure 1-1: Study research methods

Source: Steer-ED, 2023

[1] In this report, the term 'software sector' is used to refer to software-intensive businesses, which are primarily developing software functionality, products and services for use by external or internal customers (rather than just using off-the-shelf software). The term 'software economy' refers to these businesses *plus* the people in software-related occupations in other industries.

1.5 The study has drawn on the following research methods (more detail on each of the specific research methods is provided in the relevant report Sections):

- Desk research, including:
  - Analysis of data by Standard Industrial Classification (SIC) codes and Standard Occupational Classification (SOC) codes, using data from the Business Register and Employment Survey (BRES), UK Business Counts and the Annual Population Survey (APS);
  - Searches for key IT technology skills on LinkedIn and Adzuna (a search engine for job advertisements);
  - Analysis of job postings data from Lightcast;
  - Developing a database of software-intensive companies with operations in Northern Ireland, including employment information and website addresses;
  - A clustering analysis of these companies, based on text scraped from their websites;
  - Analysis of information from OpenAlex API on journal articles involving authors from Queen's University Belfast or Ulster University over the last ten years, which have been tagged with a 'computer science' concept;
  - Analysis of data from various other sources, including the Higher Education Statistics Agency, the Joint Council for Qualifications, the Council for the Curriculum, Examinations & Assessment, UCAS, NI's Department of Education, fDi Markets, Meetup, and HMRC's R&D Tax Credit statistics; and
  - A brief review of relevant public domain industry reports, to identify key relevant market trends.
- Stakeholder consultations – taking into account feedback from 44 structured interviews with 53 individuals (details are provided at Annex B); and
- A workshop with 21 stakeholders from business, academia and the public sector, which reviewed the study's draft findings and recommendations.

Mapping to DfE's Study Objectives

1.6 The table below confirms how each of the study's eight research objectives are addressed.

Table 1-1: Addressing DfE's study objectives

Study objective	Where addressed
1. Identify and prioritise specific technologies/specialisms within software	Sections 3, 4, 5, 6 and 8
2. Identify research and innovation capabilities	Section 4
3. Identify relevant international megatrends and 'Windows of Opportunity' for NI	Section 5
4. Assess how innovative, sustainable and inclusive NI's software economy is	Section 7
5. Develop a profile of the software sector	Section 2
6. Assess the extent of clustering activity	Section 6
7. Identify the key issues that need to be addressed	Section 6
8. Identify key recommendations for government and business	Section 8

Source: Steer-ED, 2023

2 Profile of NI's Software Economy

2.1 In this Section, we provide a brief overview of NI's software economy in terms of employment, GVA, earnings, geographic distribution, Foreign Direct Investment (FDI) and skills supply.

Key Messages

- There are c. 46,000 people employed in NI's software economy, including 16,500 in software SICs and 38,300 in software SOCs
- There is currently a major gender imbalance, however: women account for just 27% of employees in software industries, and only 17% of NI residents in software occupations
- Belfast accounts for 40% of NI's total business sites in the software-related SICs (compared with its 18% population share), and is dominant in terms of the sites which have 10 or more employees
- NI's software industries generated about £915 million in Gross Value Added (GVA) in 2021, having grown in real terms at an average of 12% p.a. since 1998
- The software sector is one of NI's best-paying industries: the median annual pay per employee in SIC 62 (Computer programming, consultancy and related activities) is 52% more than the overall NI earnings median
- In terms of skills supply, there are about 5,000 students enrolled on Computing courses at NI HEIs. Normalised for population size, NI's ratio of Computing students is somewhat higher than the UK average, but is behind that for Scotland and London. Participation in computing education at school is very low in NI; for example, Computing's share of A-level subjects sat is nearly twice as high in England.

Employment

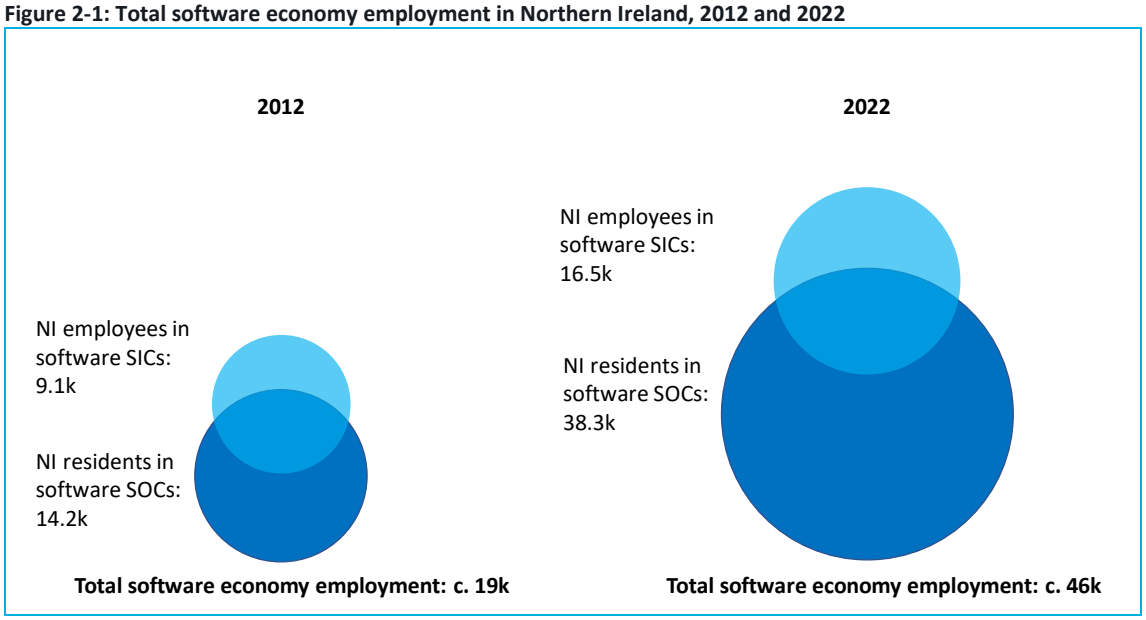
2.2 As a starting point for the study's analysis, we have drawn on the traditional data sources for assessing industries and occupations using SIC and SOC codes. The specific codes considered to be in-scope for the 'software economy' are listed in Annex A.

2.3 Considering both software-related industries (by SIC) and software-related occupations (by SOC), and accounting for the overlap between the two, we estimate that there are now **approximately 46,000 people currently involved in the software economy in NI**.

2.4 As illustrated in the Venn diagrams in Figure 2-1, this consists of c. 16,500 employees in software-related industries (including finance, human resources, and sales & marketing functions in these businesses as well as the software professionals) and c. 38,300 NI residents who are in software-related occupations (some of which are in software businesses, but many of which are in other industries such as financial services, healthcare, wholesale & retail,

public administration and manufacturing). We estimate that the overlap between these two (i.e. software occupations within software businesses) was about 8,600 people in 2022.[2]

Figure 2-1: Total software economy employment in Northern Ireland, 2012 and 2022

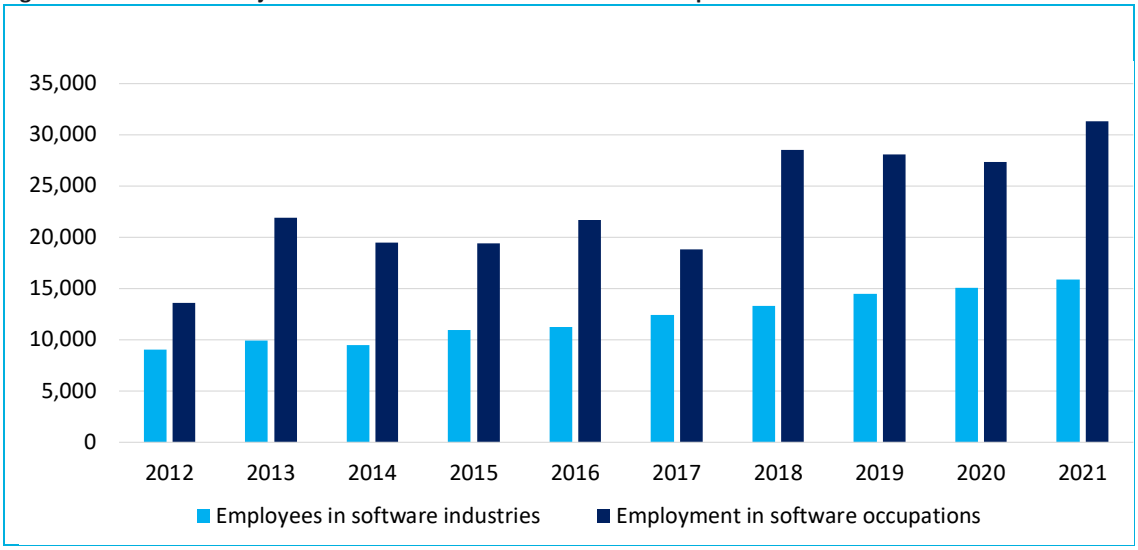


Source: Steer-ED, 2023 based on analysis of data from NI BRES, NI Quarterly Employment Survey, and Annual Population Survey

2.5 Figure 2-1 illustrates the substantial scaling up of NI's software economy over the last decade: from about 19,000 people in 2012 to c. 46,000 people in 2022. Figure 2-2 below shows time series estimates for software industry and software occupation jobs.

[2] We have assumed that approximately 52% of jobs in software-related SICs are in software-related SOCs, informed by detailed data on occupation by industry from the England & Wales census for 2011 and assuming that a similar proportion would hold for Northern Ireland.

Figure 2-2: Time series of jobs in software-related industries and occupations[3]



Source: Annual Population Survey, NI Quarterly Employment Survey

Workforce Profile

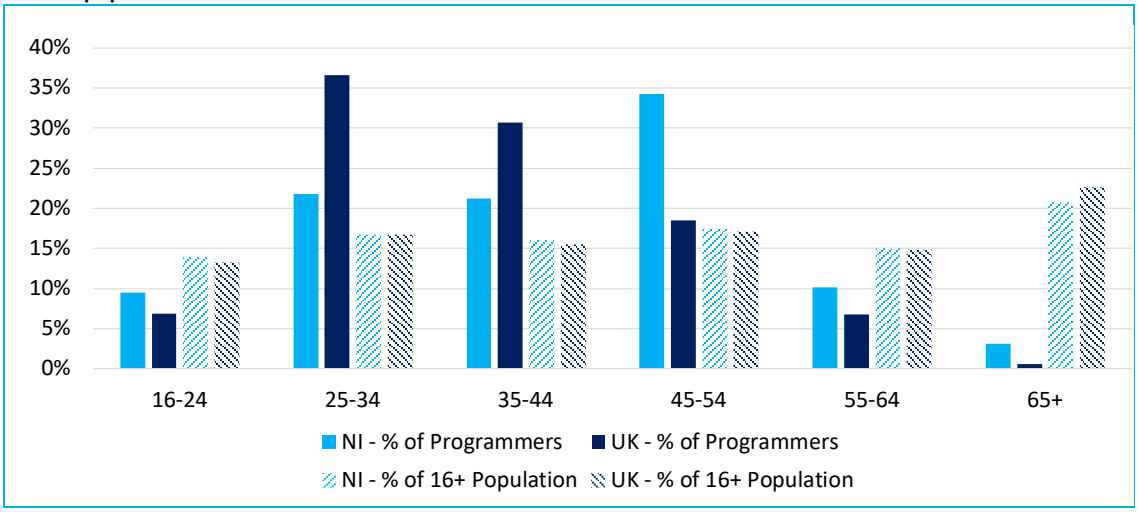
2.6 Currently, there is a **major gender imbalance** in NI's software economy: females accounted for just 27% of employees in software industries in late 2022 according to the NI Quarterly Employment Survey. Only 17% of NI residents in software occupations in 2022 were female according to the Annual Population Survey (even worse than the UK average of 20%).

2.7 The sector employs **relatively few people with a long term health problem or disability**. According to the 2021 census, only 7.4% of NI residents working in SIC 62 (Computer programming, consultancy and related activities) had a long term health problem or disability that limited their day-to-day activities, versus the Northern Ireland average of 11.0%.

2.8 An analysis of Annual Population Survey data from ONS for 2018 suggests that **the software workforce may be somewhat older on average in NI than it is in the UK** as a whole. As shown in Figure 2-3, the proportion of programmers and software development professionals aged under 45 was lower in NI (53%) than in the UK (74%) in 2018.

[3] For this time series we have used SIC 62 (Computer programming, consultancy and related activities) as a proxy for software industries, and SOC 213 (Information Technology and Telecommunications Professionals) plus SOC 313 (Information Technology Technicians) as a proxy for software occupations. Note that both sources are based on surveys and are therefore subject to significant error margins: the chart is to illustrate the overall trends over time, rather than specific year-on-year changes.

Figure 2-3: Age-band shares in 2018 for NI and UK of Programmers & software development professionals, and of the 16+ population

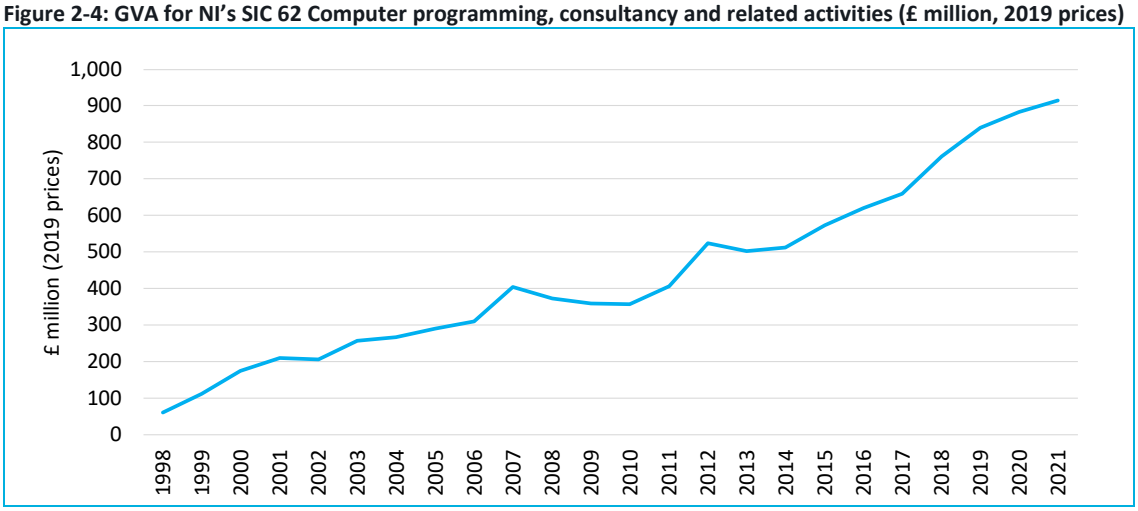


Source: Employment by detailed occupation and industry by sex and age for Great Britain, UK and constituent countries 2018, ONS, May 2019, and ONS mid-year population estimates

Gross Value Added (GVA)

2.9 NI's software industries generated about **£915 million of GVA** in 2021, according to the Office for National Statistics (Figure 2-4).

Figure 2-4: GVA for NI's SIC 62 Computer programming, consultancy and related activities (£ million, 2019 prices)

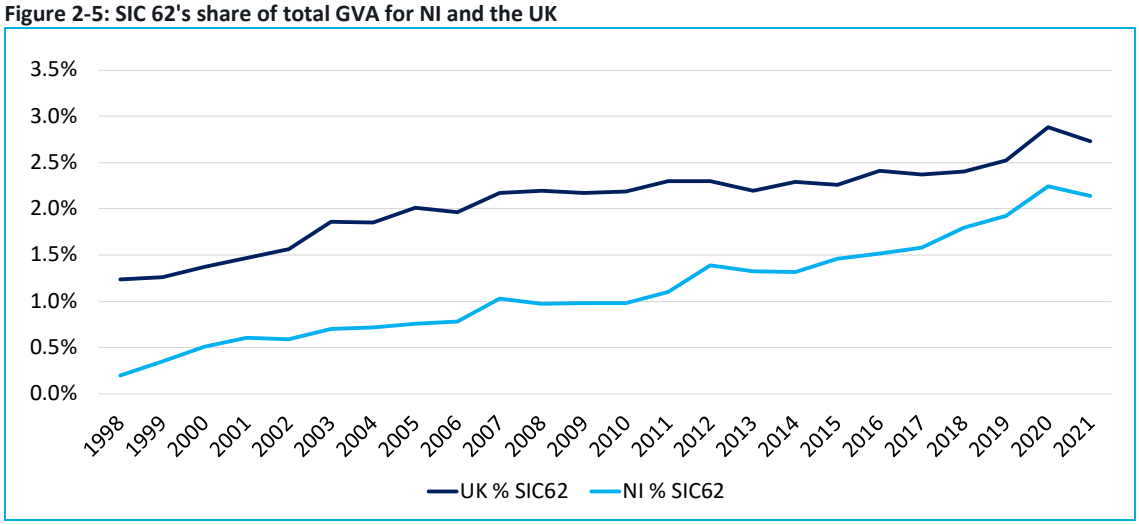


Source: Regional gross value added (balanced) by industry[4], ONS, April 2023

2.10 Having grown in real terms at a Compound Annual Growth Rate of 12% p.a. since 1998, compared with 1.4% p.a. over the same period for NI's economy as a whole, the software sector's share of overall GVA has increased strongly in NI and is now catching up with that for the UK (Figure 2-5). In 2021, SIC 62 (Computer programming, consultancy and related activities) accounted for 2.1% of NI's GVA (versus 2.7% of UK GVA)

[4] See Regional accounts methodology guide: June 2019 for the methodology used by ONS to determine regional GVA

Figure 2-5: SIC 62's share of total GVA for NI and the UK



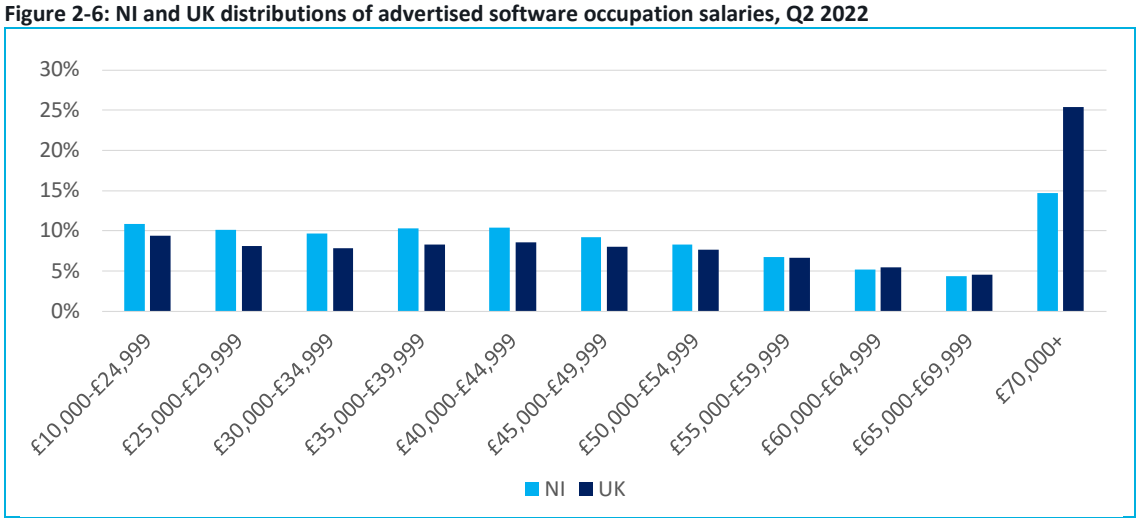
Source: Regional gross value added (balanced) by industry, ONS, April 2023

Earnings

2.11 **The software sector is one of NI's best-paying industries**. The Annual Survey of Hours and Earnings for NI estimated that the median annual pay per employee in SIC 62 (Computer programming, consultancy and related activities) was £36,710 in 2021: 52% more than the overall NI earnings median of £24,099.

2.12 Data from Lightcast suggest, however, that **software occupation salaries are still somewhat lower in NI than they are for the UK as a whole**. Figure 2-6 shows that the proportion of software occupation job ads with advertised salaries of less than £60,000 p.a. is higher in NI than in the UK as a whole, while the proportion offering a salary of £70,000 p.a. or more is significantly lower in NI than in the UK.

Figure 2-6: NI and UK distributions of advertised software occupation salaries, Q2 2022



Source: Job Posting Analytics, Lightcast Q2 2022

Geographic Distribution

2.13 Looking at the geographic distribution of business sites (Table 2-1), we see **that Belfast accounts for 40% of NI's total local units in the software-related SICs (compared with its 18% population share[5]), and is dominant in terms of the sites which have 10 or more employees**[6].

Table 2-1: Count of local units in software-related SICs by district and site size, 2022

District	Micro(0 – 9)	Small (10 – 49)	Medium (50 – 249)	Large (250+)	Total	Share of NI sites	Share of NI pop'n
Belfast	515	90	35	5	**650**	40%	18%
Lisburn and Castlereagh	150	5	0	0	**155**	10%	8%
Ards and North Down	115	5	0	0	**120**	7%	9%
Armagh City, Banbridge & Craigavon	115	5	0	0	**120**	7%	12%
Newry, Mourne and Down	110	0	0	0	**115**	7%	10%
Antrim and Newtownabbey	95	5	5	0	**105**	7%	8%
Derry City and Strabane	85	10	5	0	**100**	6%	8%
Causeway Coast and Glens	65	5	0	0	**70**	4%	7%
Mid and East Antrim	65	0	0	0	**65**	4%	7%
Mid Ulster	60	5	0	0	**65**	4%	8%
Fermanagh and Omagh	45	0	0	0	**50**	3%	6%
Total	**1,415**	**135**	**50**	**10**	**1,610**	**100%**	**100%**

Source: UK Business Counts for 2022; ONS Population Estimates for 2021

2.14 Lisburn and Castlereagh is the only other district for which its share of software-related local units (10%) outweighs its population share (8%).

2.15 The significant increase in remote and hybrid working, however, raises some interesting implications for how the geographic distribution of economic activity is measured – particularly in the software sector. In practice, many of the people working for Belfast-based software businesses will be spending a significant proportion of their working days at home in other districts; so the regional benefits of economic activity in the software sector will be more widely-spread than is suggested by the local unit analysis.

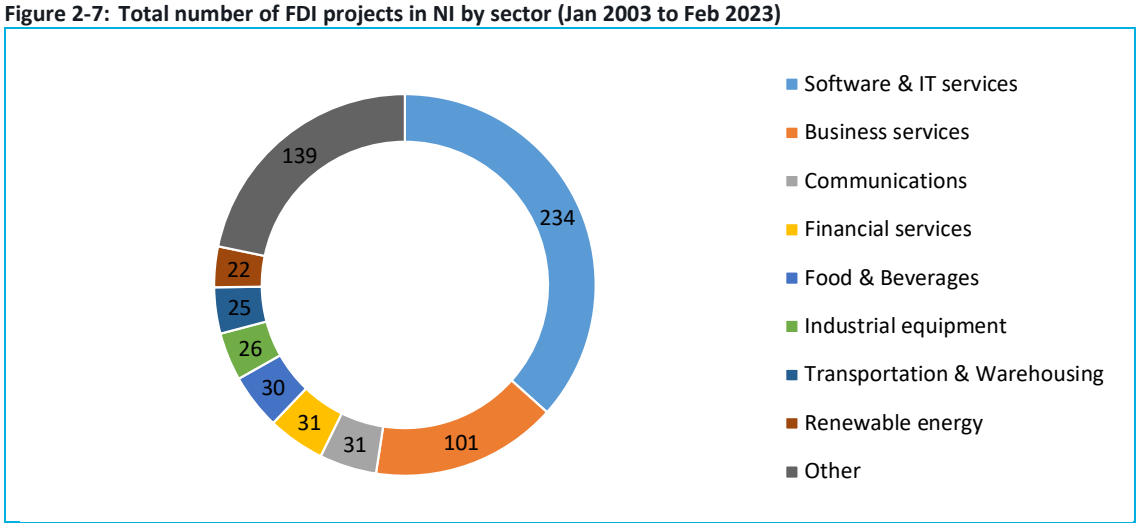
Foreign Direct Investment (FDI)

2.16 NI's success in attracting FDI has contributed a substantial part of the growth of NI's software economy. Between January 2003 and February 2023, fDi Markets records 234 FDI projects in the Software and IT Services sector: by far the greatest number of any sector (Figure 2-7).

[5] A 40% share is also high relative to Belfast's share of NI's total employment (30%) and its share of NI's total local units (16%).

[6] Note that these numbers are rounded to the nearest 5, so '0' may not actually be zero in the small, medium and large columns.

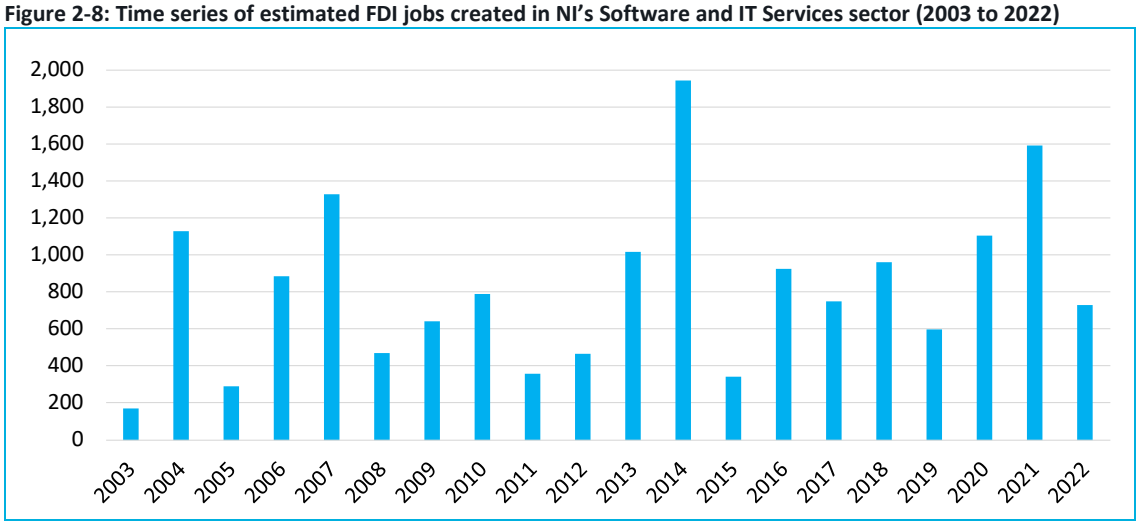
Figure 2-7: Total number of FDI projects in NI by sector (Jan 2003 to Feb 2023)



Source: fDi Markets, 2023

2.17 The time series of estimated jobs associated with NI's FDI in the Software and IT Services sector is illustrated below (Figure 2-8). Note that, in practice, the total jobs created by a given project may be realised over a number of years. The United States is by some distance the source country that has created the largest number of FDI jobs in this sector, accounting for more than 80% of the jobs estimated to have been created.

Figure 2-8: Time series of estimated FDI jobs created in NI's Software and IT Services sector (2003 to 2022)



Source: fDi Markets, 2023

Skills Supply

Higher Education

2.18 One important pathway into a software career is to obtain a Computing qualification at one of NI's Higher Education Institutions (HEIs): Queen's University Belfast (QUB), Ulster University (UU) or the Open University. There are **approximately 5,000 students enrolled on Computing courses at NI HEIs**, approximately 20% of which are postgraduates (Table 2-2 and Table 2-3). Only 24% of Computing students at NI's HEIs are female.

Table 2-2: Computing student enrolments by NI HEI and year

HEI	2019/20	2020/21	2021/22

Open University	485	595	580
Queen's University, Belfast	2,095	2,540	2,360
Ulster University	2,225	2,400	2,105
Total	**4,805**	**5,540**	**5,045**

Source: HE student enrolments by HE provider and subject of study, HESA, 2023

Table 2-3: Computing student enrolments (across all NI HEIs) by level of study and year

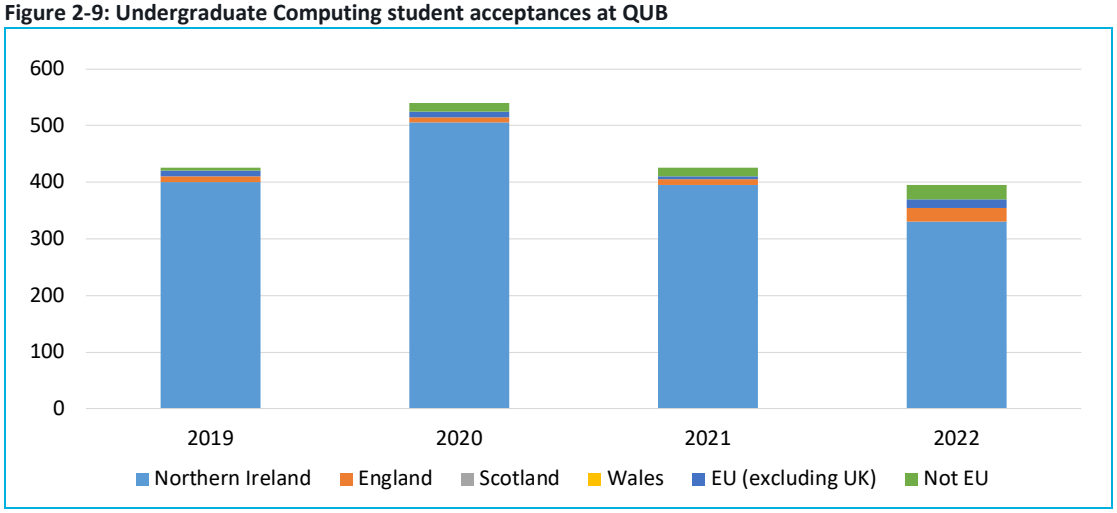
Level of study	2019/20	2020/21	2021/22
Undergraduate	3,935	4,190	4,050
Postgraduate	870	1,350	995
Total	**4,805**	**5,540**	**5,045**

Source: HE student enrolments by HE provider and subject of study, HESA, 2023

2.19 In addition to these students at university, there were a further 1,099 enrolments for Information and Communication Technology courses at Higher Education (HE) level in NI's Further Education (FE) sector in 2021/22.

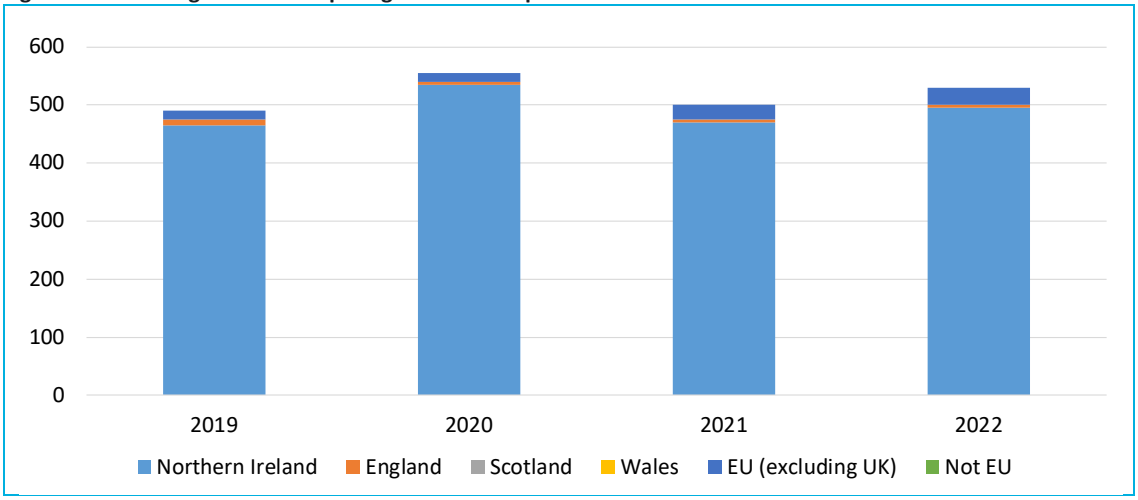
2.20 Notwithstanding the strong growth of the sector described above, **undergraduate acceptances for Computing have been broadly flat** in recent years at Queen's University Belfast (QUB) and Ulster University (UU), as illustrated in Figure 2-9 and Figure 2-10.

Figure 2-9: Undergraduate Computing student acceptances at QUB



Source: Provider-level end of cycle data resource for the 2022 application cycle, UCAS

Figure 2-10: Undergraduate Computing student acceptances at UU

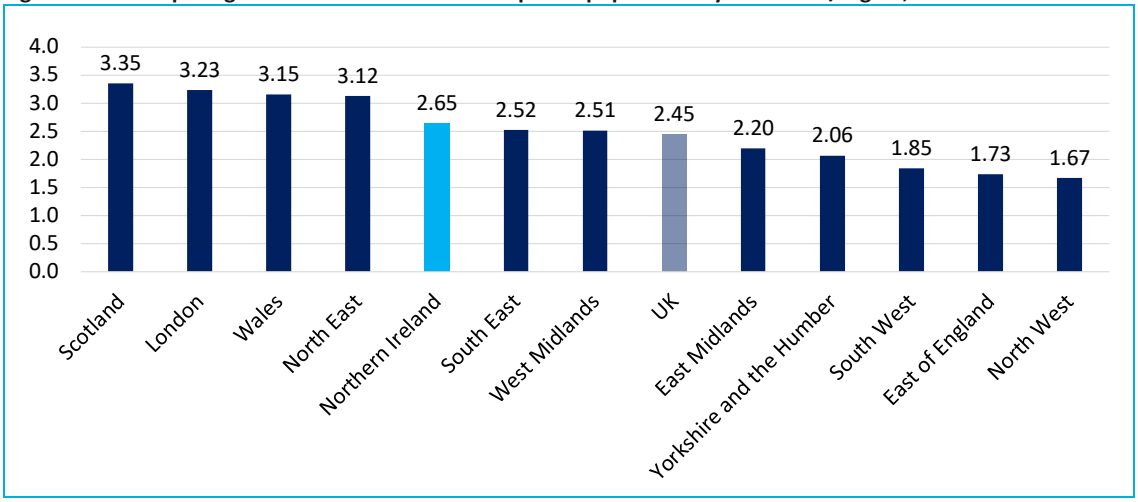


Source: Provider-level end of cycle data resource for the 2022 application cycle, UCAS

2.21 Of 1,025 NI-domiciled applicants accepted onto Computing undergraduate courses in 2022, 200 (20%) moved to study outside NI.

2.22 Comparing the HEI student enrolments (undergraduate and postgraduate) in Computing per 1,000 population in the UK nations and regions, we see that NI is somewhat higher than the UK average (2.65 Computing students per thousand population vs 2.45 for the UK), but significantly behind Scotland (3.35) and London (3.23) by this skills supply metric.

Figure 2-11: Computing student enrolments at HEIs per 1k population by UK nation/region, 2021-22



Source: HE student enrolments by HE provider and subject of study, HESA, 2023; Mid-Year Population Estimates

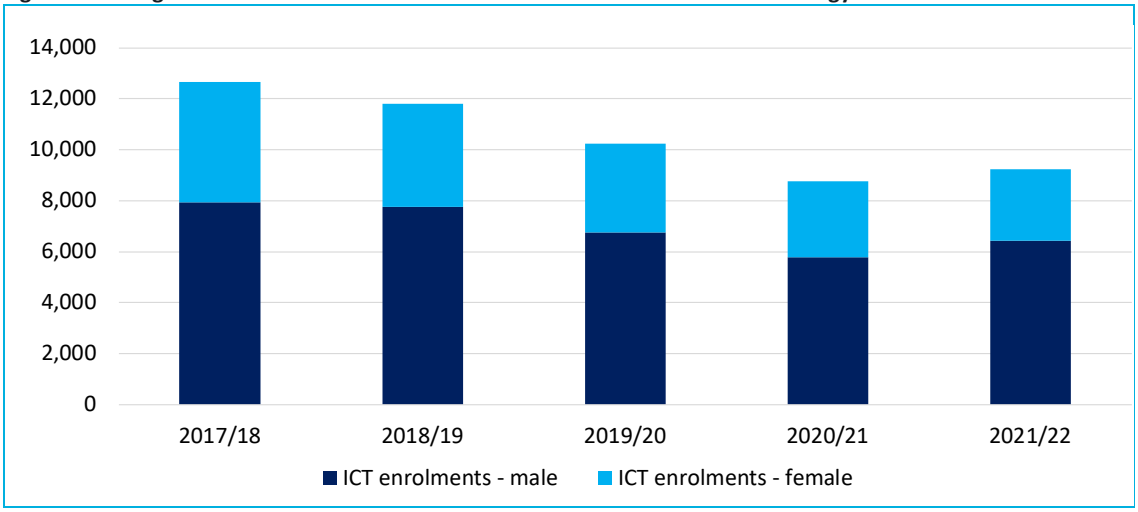
2.23 In practice, however, Computing degrees are not the only route into a software career. Looking more widely at other STEM subjects, we note that in 2021/22 there were **a further 5,785 students enrolled at NI HEIs in three other STEM areas**: Physical Sciences (1,075), Mathematical Sciences (635) and Engineering & Technology (4,075).

Further Education

2.24 In Further Education (FE), there were 9,245 enrolments in the Information and Communication Technology (ICT) subject area in 2021/22 (Figure 2-12). Although this was 27% lower than the number of enrolments in 2017/18, this reduction was in line with the overall

trend in FE enrolments in NI; ICT's share of total FE enrolments held steady at about 10% over the period.

Figure 2-12: Regulated FE enrolments in Information and Communication Technology in NI



Source: Further Education Sector activity in Northern Ireland by Assembly Area: 2017/18 to 2021/22, DfE, June 2023

A-Levels

2.25 At A level, relatively few NI students sit Computing. In summer 2022, the 357 entries for Computing accounted for just 1.1% of subjects sat in NI, and only 12.3% of candidates were female. However, the grades achieved by those who did sit Computing were high in NI: 76% achieving A* to B grades in NI versus 58% for the UK as a whole (Table 2-4).

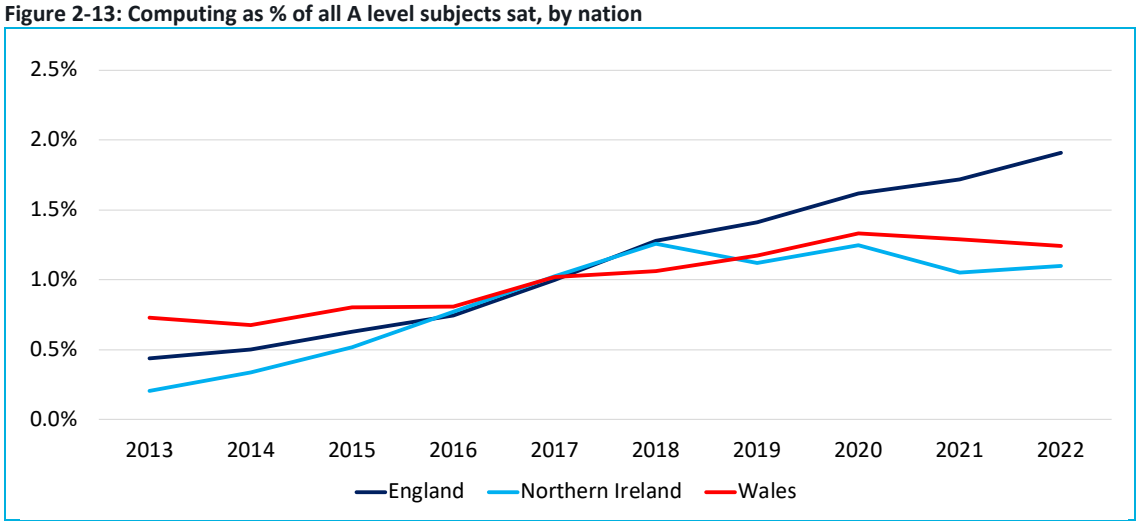
Table 2-4: Computing A levels sat in Summer 2022 as % of all subjects sat, by UK nation

	Students sitting Computing A level	Computing as % of all subjects sat	% A* to B	% female
UK	15,693	1.8%	57.9%	15.0%
England	14,809	1.9%	57.6%	15.2%
Northern Ireland	**357**	**1.1%**	**75.9%**	**12.3%**
Wales	441	1.2%	54.4%	12.9%

Source: Joint Council for Qualifications GCE A Level & GCE AS Level Results Summer 2022

2.26 Figure 2-13 illustrates how Computing's 'share' of subjects sat at A level has developed over the last decade in Northern Ireland, England and Wales. It is striking that the proportion for England is now nearly double that for NI, despite both nations being similar in 2017. This may well be partly thanks to computer science education becoming a mandated part of the curriculum through to KS4 in England from 2014.

Figure 2-13: Computing as % of all A level subjects sat, by nation



Source: Joint Council for Qualifications GCE A Level & GCE AS Level Results

GCSE

2.27 At GCSE level, student numbers are again very low for Computing in NI. With 867 entries, the Digital Technology Programming option accounted for just 0.6% of GCSE subjects sat in summer 2022, and only 24% of its candidates were female. Again, those that did take this course achieved high grades, however: 76% achieving A* to B grades compared with the NI average of 62% across all subjects (Table 2-5).

Table 2-5: Digital Technology (Multimedia and Programming) GCSEs sat in NI in summer 2022

	Students sitting subject at GCSE	% of all subjects sat	% A* to B	% female
Digital Technology Multimedia	2,301	1.6%	70.3%	35.2%
Digital Technology Programming	**867**	**0.6%**	**76.4%**	**23.5%**
All Digital Technology	3,168	2.2%	72.0%	32.0%
All subjects	142,895	100%	62.0%	51.7%

Source: CCEA, GCSE Results – Summer 2022

3 Software Technology/Specialism Strengths and Needs in NI

Key Messages

- SIC 6201 (Computer programming activities) is an area in which NI has a genuine and significant specialisation
- NI has done well in developing and attracting larger business sites in the field of software development, but is considerably underweight in terms of the presence of micro businesses in software-related areas
- The share of total employment in software-related occupations is rather lower in NI than it is in GB excluding London, but NI has a relative specialism in SOC 2134 (Programmers and software development professionals)
- Analysis of technologies mentioned on LinkedIn and Adzuna suggests that NI is particularly strong in core software engineering technologies such as C#, Java and JavaScript. However, mentions of AI, Machine Learning and Data Science look relatively low, and employment in these areas may be growing more rapidly elsewhere in the UK than they are in NI
- Applying textual analysis and a k-means clustering technique to text scraped from software-intensive companies' websites, we see that the strongest areas of specialism in NI are FinTech, Digital Transformation, Cyber, Data Analytics, and Sensing, Control & Automation

SIC/SOC Analysis

3.1 As a starting point for the study's analysis, we have drawn on the traditional data sources for assessing industries and occupations using SIC and SOC codes. The specific codes considered to be in-scope for software are listed in Annex A.

3.2 Where appropriate, we have compared the Northern Ireland situation to that in Great Britain (excluding London). For these comparisons London has been excluded from the GB figures as it is so dominant in the UK's tech sector, and skews the national averages. The share of NI's employees (or local units) in each SIC or SOC has been divided by the equivalent share in GB excluding London, to give a Location Quotient (LQ). A LQ above 1.0 indicates that NI is relatively specialised in that industry or occupation, compared to GB excluding London.

Employees by SIC

3.3 First, we have looked at the number of employees per SIC at 3-digit and 4-digit level. Overall, there were **approximately 16,500 employees in these SICs** in September 2021. Table 3-1 shows that NI is roughly on a par with GB excluding London in SIC 620 (Computer programming, consultancy and related activities), but that SICs 582 (Software publishing) and 631 (Data processing, hosting and related activities; web portals) are relatively under-represented in NI. Drilling down to 4-digit level (Table 3-2), however, we see that **SIC 6201**

(Computer programming activities) is an area in which NI has a genuine and significant specialisation, with a LQ of 1.67 compared with GB excluding London.

Table 3-1: Employees per 3-digit SIC

SIC	NI Employee jobs Sept 2021	Share of NI employees	NI LQ vs GB excl London
582 : Software publishing	86	0.01%	0.23
620 : Computer programming, consultancy and related activities	16,140	2.07%	0.97
631 : Data processing, hosting and related activities; web portals	263	0.03%	0.27

Source: NI BRES, GB BRES for 2021

Table 3-2: Employees per 4-digit SIC

SIC	NI Employee jobs Sept 2021	Share of NI employees	NI LQ vs GB excl London
5821 : Publishing of computer games	~		
5829 : Other software publishing	~		
6201 : Computer programming activities	**7,945**	**1.02%**	**1.67**
6202 : Computer consultancy activities	6,202	0.79%	0.72
6203 : Computer facilities management activities	-		
6209 : Other information technology and computer service activities	1,992	0.26%	0.63
6311 : Data processing, hosting and related activities	228	0.03%	0.28
6312 : Web portals	35	0.00%	0.22

Source: NI BRES, GB BRES (~ = not disclosed due to confidentiality)

Local Units by SIC

3.4 Regarding the number of 'local units' (effectively, business sites), ONS's UK Business Counts reports that there were approximately 1,610 local units in relevant SICs in Northern Ireland in 2022. Of those, the vast majority were micro business sites (with 0 to 9 employees); these accounted for 1,415 (88%) of the sites.

3.5 However, **the software SICs' share of NI's total micro business sites is considerably less than it is in GB excluding London**. As shown in Table 3-3, the highest LQ is just 0.77, for SIC 62012 (Business and domestic software development).

Table 3-3: Local units by SIC – micro (0 to 9 employees)

SIC	NI local units 2022	Share of NI micro local units	NI LQ vs GB excl London
58210 : Publishing of computer games	5	0.01%	0.54
58290 : Other software publishing	15	0.02%	0.26
62011 : Ready-made interactive leisure & entertainment software dev't	15	0.02%	0.39

SIC	NI local units 2022	Share of NI micro local units	NI LQ vs GB excl London
62012 : Business and domestic software development	**510**	**0.65%**	**0.77**
62020 : Computer consultancy activities	710	0.90%	0.34
62030 : Computer facilities management activities	10	0.01%	0.53
62090 : Other information technology and computer service activities	110	0.14%	0.25
63110 : Data processing, hosting and related activities	25	0.03%	0.33
63120 : Web portals	10	0.01%	0.30

Source: UK Business Counts

3.6 The picture changes, however, when looking at larger sites: in that same sub-sector (62012 : Business and domestic software development) the LQ versus GB excluding London rises to 1.05 for small sites (10 to 49 employees) and 1.81 for medium sites (50 to 249 employees).

Table 3-4: Local units by SIC – small (10 to 49 employees)

SIC	NI local units 2022	Share of NI small local units	NI LQ vs GB excl London
58210 : Publishing of computer games	0	0.00%	0.00
58290 : Other software publishing	5	0.04%	0.79
62011 : Ready-made interactive leisure & entertainment software dev't	0	0.00%	0.00
62012 : Business and domestic software development	**70**	**0.59%**	**1.05**
62020 : Computer consultancy activities	35	0.30%	0.38
62030 : Computer facilities management activities	0	0.00%	0.00
62090 : Other information technology and computer service activities	20	0.17%	0.45
63110 : Data processing, hosting and related activities	5	0.04%	0.42
63120 : Web portals	0	0.00%	0.00

Source: UK Business Counts

Table 3-5: Local units by SIC – medium (50 to 249 employees)

SIC	NI local units 2022	Share of NI medium local units	NI LQ vs GB excl London
58210 : Publishing of computer games	0	0.00%	0.00
58290 : Other software publishing	0	0.00%	0.00
62011 : Ready-made interactive leisure & entertainment software dev't	0	0.00%	0.00
62012 : Business and domestic software development	**25**	**1.12%**	**1.81**
62020 : Computer consultancy activities	15	0.67%	0.79
62030 : Computer facilities management activities	0	0.00%	0.00
62090 : Other information technology and computer service activities	5	0.22%	0.61
63110 : Data processing, hosting and related activities	0	0.00%	0.00
63120 : Web portals	0	0.00%	0.00

Source: UK Business Counts

3.7 Similarly, the LQ versus GB excluding London rises for the larger sites in SIC 62020 (Computer consultancy activities), albeit still remaining below 1.0: the LQ for this sector rises from 0.34 for the micro sites to 0.79 for the medium sites.

3.8 Note that these numbers are rounded to the nearest 5, so '0' may not actually be zero. The figures for *large* local units (250+ employees) are skewed by these roundings (there are 10 such NI sites in software SICs), so comparisons with GB excluding London are not reliable.

3.9 Overall, the local units data confirm that **NI has done well in developing and attracting larger business sites in the field of software development, but is considerably underweight in terms of the presence of micro businesses in software-related areas**. While start-up rates are generally relatively low in NI[7], the analysis above – comparing the software sector's share of micro business sites in NI with that in GB excluding London - suggests that the issue is particularly pronounced in this sector.

Employment by Occupation

3.10 Another perspective on NI's software activities is provided by looking at software-related *occupations*. This provides information on people in software-related jobs, whether or not they are working in the software-related industries that are considered above. In the year to December 2022 there was **total NI employment of 38,300 in software-related occupations** according to the Annual Population Survey[8].

[7] NI had the lowest business birth rate of the UK nations and regions in 2021, according to **Business demography, UK: 2021**, ONS, November 2022

[8] Note that NI's Census 2021 estimated 24,757 people in SOCs 213, 214 and 313 as at census day (21 March 2021) – considerably lower than the 35,200 in these codes estimated by the Annual Population Survey for the year to December 2022. We have chosen to use APS estimates here because they are more recent, they allow for consistent comparison with GB data, they will be updated more frequently, and they are available at a more detailed level (4 digit SOC) than is currently the case for the census data. It is beyond the scope of this study to resolve apparent inconsistencies between census and APS estimates for occupations, which

Table 3-6: Employment per 3-digit SOC (SOC2020)

SOC	NI employment	Share of NI employment	NI LQ vs GB excl London
213 : Information Technology Professionals	29,300	3.34%	0.91
214 : Web and Multimedia Design Professionals	#1,200	0.14%	0.36
313 : Information Technology Technicians	4,700	0.54%	0.62

Source: Annual Population Survey for 12 months to December 2022 (# = potentially unreliable estimate as the APS group sample size was small)

Table 3-7: Employment per 4-digit SOC (SOC2020)

SOC	NI employment	Share of NI employment	NI LQ vs GB excl London
1137 : Information technology directors	2,500	0.28%	0.58
2131 : IT project managers	2,000	0.23%	0.68
2132 : IT managers	2,800	0.32%	0.48
2133 : IT business analysts, architects and systems designers	**4,200**	**0.48%**	**1.04**
2134 : Programmers and software development professionals	**14,800**	**1.69%**	**1.17**
2135 : Cyber security professionals	**#1,600**	**0.18%**	**1.46**
2136 : IT quality and testing professionals	~		
2137 : IT network professionals	#1,200	0.14%	0.94
2139 : Information technology professionals n.e.c.	2,400	0.27%	0.74
2141 : Web design professionals	~		
2142 : Graphic and multimedia designers	#900	0.10%	0.34
3131 : IT operations technicians	2,600	0.30%	0.83
3132 : IT user support technicians	#1,500	0.17%	0.53
3133 : Database administrators and web content technicians	#600	0.07%	0.36
3573 : Information technology trainers	**#600**	**0.07%**	**2.09**

Source: Annual Population Survey for 12 months to December 2022 (~ = not disclosed due to confidentiality; # = potentially unreliable estimate as the APS group sample size was small)

3.11 Table 3-6 highlights that **the share of total employment in software-related occupations[9] is rather lower in NI than it is in GB excluding London**, especially for SOC 214 (Web and Multimedia Design Professionals) and SOC 313 (Information Technology Technicians).

could potentially arise from differences in the methods by which occupations are categorised. We note that the England & Wales census estimates for these occupations were also considerably lower than the APS estimates.

[9] See Annex A for ONS's descriptions of each of the SOC2020 occupation codes

However, drilling down to 4-digit SOC codes, we see in Table 3-7 that **NI has a relative specialism in SOC 2134 (Programmers and software development professionals)** with an estimated 14,800 people in such occupations and a LQ of 1.17 versus GB excluding London, and in **SOC 2133 (IT business analysts, architects and systems designers)** with about 4,200 people in these occupations and a LQ of 1.04. There are higher LQs for **SOC 2135 (Cyber security professionals)** and **SOC 3573 (Information technology trainers)**, but note the caveats that the estimates for these occupations are potentially unreliable given small APS sample sizes.

Technology Specialism Analysis

3.12 Software-related activities draw on a wide variety of technologies. These include: operating systems (e.g. Linux, Unix, Windows); protocols (e.g. HTTP, TCP/IP); programming languages (e.g. C#, Java, Python); database systems (e.g. MySQL, MongoDB); virtualisation, containerisation and cloud technologies (e.g. virtual machines, AWS, Azure, Kubernetes); AI algorithms and frameworks (e.g. TensorFlow, PyTorch); and open source software (e.g. Python libraries, Apache Spark).

3.13 Such underpinning technologies are the result of continuous innovation across the world: they are global technologies. To understand where NI's relative strengths are with respect to these *technologies*, we need to assess the *skills* base: how does NI fare in terms of the numbers of people with skills in specific technologies? Such information is not available from traditional datasets such as the surveys run by ONS, so we extract insights from less traditional data sources in the sub-sections below.

LinkedIn

3.14 The study has reviewed a list of the top IT technology skills in demand in the UK as of February 2023 from **jobtensor.com** and searched LinkedIn to see how many members' profiles mention each of those technologies in NI and in the UK[10].

3.15 Figure 3-1 below shows the resulting snapshot of the total number of NI LinkedIn members mentioning that technology versus NI's share of total UK members mentioning the technology.

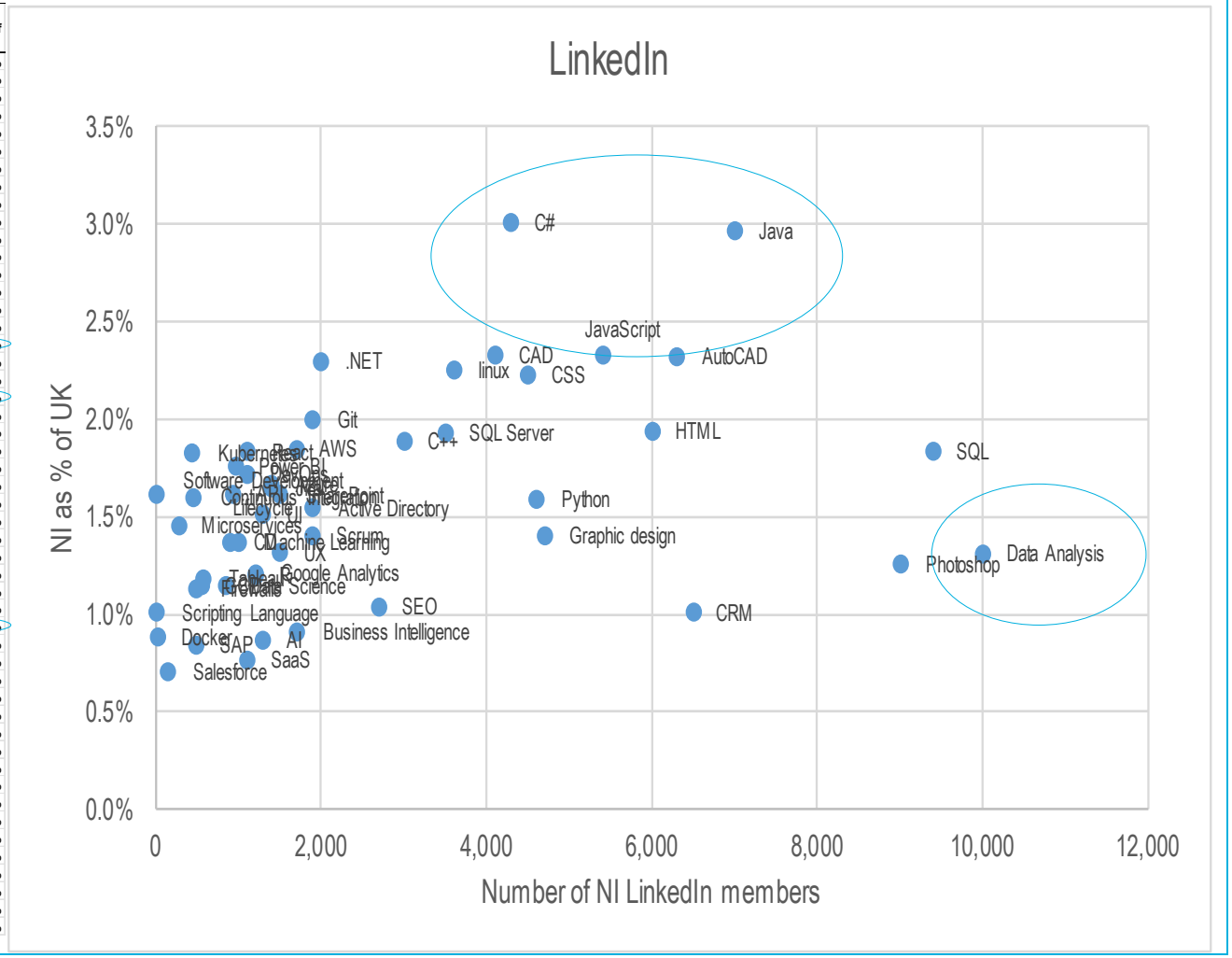
3.16 For reference, NI has 2.8% of the UK population, 2.5% of total UK employees, 2.0% of UK employees in software-related SICs, and 1.8% of UK residents in software-related SOCs. So where NI's share of the UK members' profiles mentioning the relevant technology goes above c. 2.0% that suggests that the technology is relatively well-represented in NI. Conversely where NI's share drops below 1.5% that would indicate that NI is as yet underweight in that technology, relative to the UK average.

3.17 The high prevalence of C#, Java and JavaScript amongst NI-based members of LinkedIn indicates that **Northern Ireland is particularly strong in these core software engineering technologies**. However, **NI's shares of the mentions of AI (0.9%), Machine Learning (1.4%) and Data Science (1.1%) look relatively low**, notwithstanding the important relevant capabilities in NI's universities and companies.

[10] Although LinkedIn is a large and useful source for gaining insights into job types and skills availability by geography, it should be borne in mind that it has limitations for this purpose – as not all workers are on LinkedIn, and as the analysis is dependent on how much information is included in members' profiles.

Figure 3-1: Mentions of top 50 IT technology skills in LinkedIn profiles, in NI vs UK

Skills demand rank UK	Skill	NI number LinkedIn	UK figure LinkedIn	NI as % of UK
1	SQL	9,400	512,000	1.8%
2	Python	4,600	289,000	1.6%
3	Azure	1,400	84,000	1.7%
4	Data Analysis	10,000	761,000	1.3%
5	SAP	491	58,000	0.8%
6	AWS	1,700	92,000	1.8%
7	DevOps	1,100	64,000	1.7%
8	Software Development Life	6	371	1.6%
9	CRM	6,500	644,000	1.0%
10	Power BI	967	55,000	1.8%
11	JavaScript	5,400	232,000	2.3%
12	AutoCAD	6,300	271,000	2.3%
13	Java	7,000	236,000	3.0%
14	Continuous Integration	448	28,000	1.6%
15	C#	4,300	143,000	3.0%
16	CAD	4,100	176,000	2.3%
17	AI	1,300	150,000	0.9%
18	API	939	58,000	1.6%
19	linux	3,600	160,000	2.3%
20	Machine Learning	1,000	73,000	1.4%
21	HTML	6,000	309,000	1.9%
22	CD	892	65,000	1.4%
23	SharePoint	1,500	93,000	1.6%
24	Scrum	1,900	135,000	1.4%
25	Salesforce	141	20,000	0.7%
26	Business Intelligence	1,700	186,000	0.9%
27	Scripting Language	1	99	1.0%
28	Jira	1,400	85,000	1.6%
29	Photoshop	9,000	715,000	1.3%
30	Active Directory	1,900	123,000	1.5%
31	SEO	2,700	259,000	1.0%
32	CSS	4,500	202,000	2.2%
33	Data Science	850	74,000	1.1%
34	C++	3,000	159,000	1.9%
35	Tableau	580	49,000	1.2%
36	UX	1,500	114,000	1.3%
37	R	1,200	100,000	1.2%
38	SQL Server	3,500	181,000	1.9%
39	Firewalls	486	43,000	1.1%
40	.NET	2,000	87,000	2.3%
41	React	1,100	60,000	1.8%
42	SaaS	1,100	143,000	0.8%
43	Kubernetes	438	24,000	1.8%
44	Git	1,900	95,000	2.0%
45	GCP	550	48,000	1.1%
46	Docker	15	1,700	0.9%
47	Microservices	277	19,000	1.5%
48	Google Analytics	1,200	99,000	1.2%
49	UI	1,300	86,000	1.5%
50	Graphic design	4,700	335,000	1.4%



Source: LinkedIn, jobtensor.com, February 2023

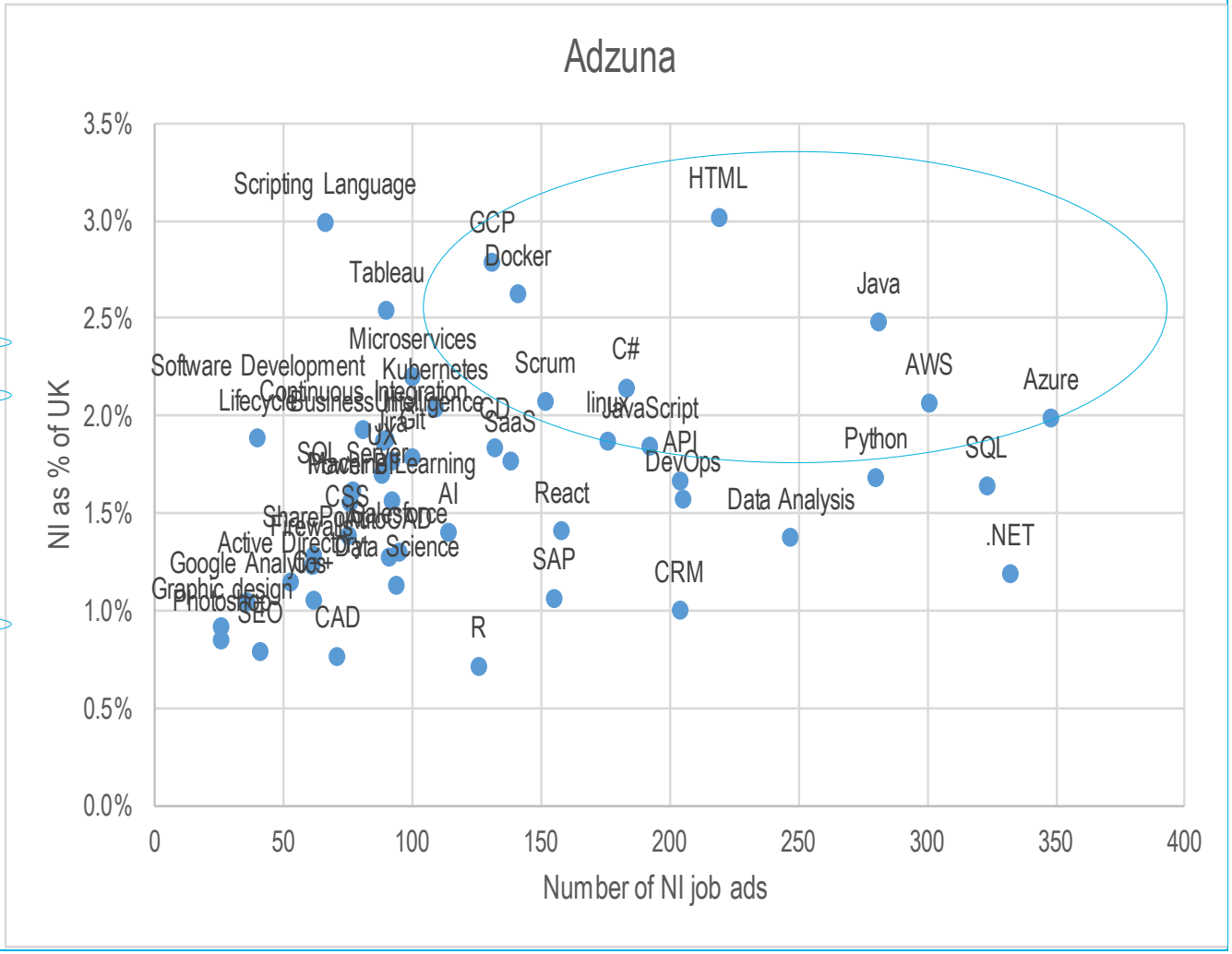
Adzuna

3.18 Running a similar snapshot analysis on the same technologies using Adzuna, the job search engine, the **core software engineering technologies of C#, Java, JavaScript and HTML are again well-represented** in the current adverts for new jobs based in Northern Ireland (Figure 3-2 below). We also see relatively high demand for cloud-based skills of Azure, AWS and GCP (Google Cloud Platform) technologies, and for Docker which is a software platform that allows developers to build, test, and deploy applications quickly on servers and the cloud.

3.19 As with the LinkedIn analysis, though, **NI's share of UK job adverts mentioning AI (1.4%), Machine Learning (1.6%) and Data Science (1.1%) look relatively low** – suggesting that employment in these areas may be growing more rapidly elsewhere in the UK than they are in NI. Given the increasing importance of these disciplines in generating and informing future products and services across the economy, this may be an area requiring concerted effort to further strengthen NI's capabilities.

Figure 3-2: Mentions of top 50 IT technology skills in job adverts found through Adzuna, in NI vs UK

Skills demand rank UK	Skill	Adzuna - NI jobs	Adzuna - UK jobs	NI as % of UK
1	SQL	323	19,766	1.6%
2	Python	280	16,655	1.7%
3	Azure	348	17,536	2.0%
4	Data Analysis	247	18,033	1.4%
5	SAP	155	14,584	1.1%
6	AWS	301	14,614	2.1%
7	DevOps	205	13,097	1.6%
8	Software Development Life	40	2,128	1.9%
9	CRM	204	20,451	1.0%
10	Power BI	76	4,910	1.5%
11	JavaScript	192	10,434	1.8%
12	AutoCAD	91	7,169	1.3%
13	Java	281	11,350	2.5%
14	Continuous Integration	81	4,209	1.9%
15	C#	183	8,542	2.1%
16	CAD	71	9,322	0.8%
17	AI	114	8,144	1.4%
18	API	204	12,280	1.7%
19	linux	176	9,427	1.9%
20	Machine Learning	92	5,910	1.6%
21	HTML	219	7,262	3.0%
22	CD	132	7,203	1.8%
23	SharePoint	62	4,837	1.3%
24	Scrum	152	7,344	2.1%
25	Salesforce	95	7,320	1.3%
26	Business Intelligence	90	4,809	1.9%
27	Scripting Language	66	2,210	3.0%
28	Jira	92	5,202	1.8%
29	Photoshop	26	3,067	0.8%
30	Active Directory	53	4,627	1.1%
31	SEO	41	5,206	0.8%
32	CSS	75	5,417	1.4%
33	Data Science	94	8,323	1.1%
34	C++	62	5,906	1.0%
35	Tableau	90	3,552	2.5%
36	UX	88	5,176	1.7%
37	R	126	17,694	0.7%
38	SQL Server	77	4,790	1.6%
39	Firewalls	61	4,953	1.2%
40	.NET	332	27,973	1.2%
41	React	158	11,259	1.4%
42	SaaS	138	7,815	1.8%
43	Kubernetes	109	5,347	2.0%
44	Git	100	5,606	1.8%
45	GCP	131	4,699	2.8%
46	Docker	141	5,383	2.6%
47	Microservices	100	4,558	2.2%
48	Google Analytics	36	3,457	1.0%
49	UI	89	4,760	1.9%
50	Graphic design	26	2,849	0.9%

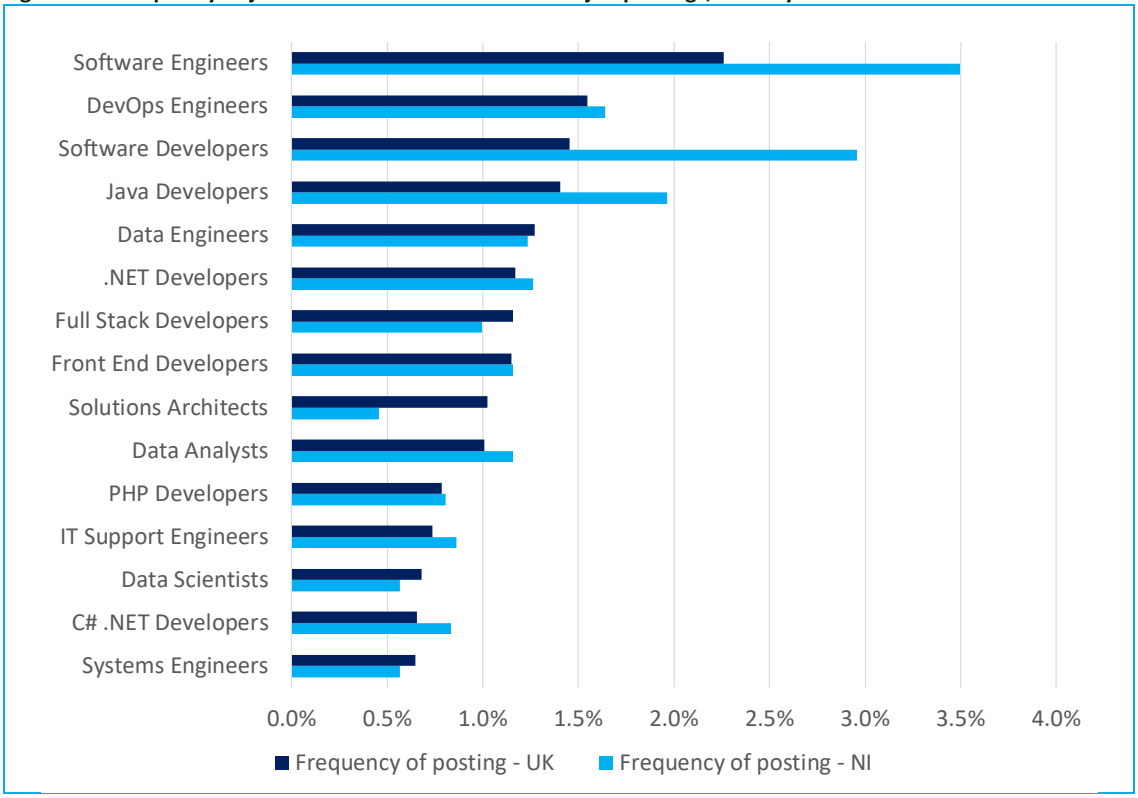


Source: Adzuna, jobtensor.com, February 2023

Lightcast

3.20 Another data source for job postings data is Lightcast, which tracks online job adverts over time. The chart in Figure 3-3 shows the top 15 titles in the UK of jobs which Lightcast has tagged as being in one of the study's software-related SOC occupations over the period January 2021 to December 2022. Note that the chart shows the *proportion* of all software jobs advertised which are for each job title, rather than a measure of absolute volumes, for NI and for the UK (including NI).

Figure 3-3: Frequency of job titles in software-related SOC job postings, January 2021 to December 2022



Source: Lightcast, February 2023

3.21 Considering the proportion of unique job ads with that job title, the distributions for the UK and NI are broadly similar, with the notable exceptions that the job titles 'Software Engineer' and 'Software Developer' are considerably more common in NI than in the UK, as is 'Java Developer'. The job titles 'Solutions Architect', 'Full Stack Developer' and 'Data Scientist' appear to be less common for jobs advertised in NI than is the case for the UK as a whole.

3.22 The relatively high prevalence in NI of the more generic job titles, Software Engineer and Software Developer may be indicative of a greater need in NI for people with a broad range of software skills, and/or a reflection that the much larger size of the UK leads to a wider scope of software-related activities being undertaken.

Company Clusters Analysis

Method

3.23 To obtain some insight into groupings of companies involved in similar or closely-related areas, the study undertook a clustering analysis based on texts scraped from companies' websites.

3.24 As input to this we pulled together a database of software-intensive companies with operations in NI, drawing from:

- FAME: selecting companies in the 'software sector' as defined by Bureau van Dyke, for companies with a registered address or primary trading address in NI;
- The Data City: companies tagged with the keyword 'software', with a registered address in NI, and at least 10 employees;
- Digital DNA's Top 100 Tech Companies in NI, 2022;
- Top recruiters for software in Northern Ireland, from Adzuna and Lightcast (excluding recruitment agencies); and
- NI companies on Deloitte Technology Fast 50 list.

3.25 We then filtered the 'longlist' of c. 2,000 companies down to c. 500, to remove companies without websites, and the smallest companies (by employment and/or current assets).

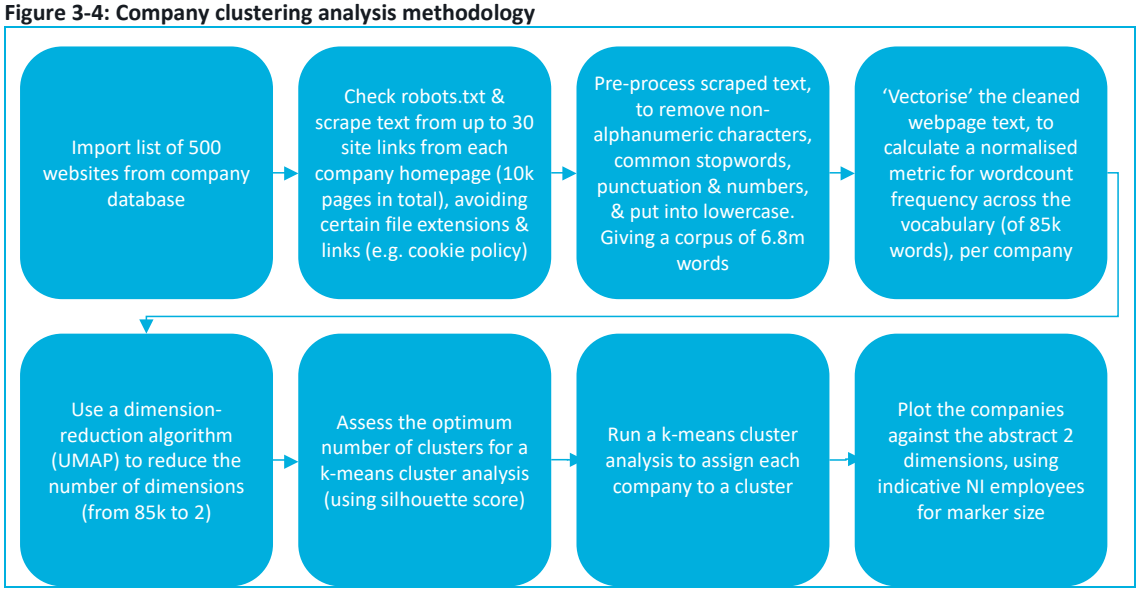
3.26 For companies registered in NI, we have included the number of employees from the latest filed accounts (where available). However, we have used the number of LinkedIn members identified as being located in Northern Ireland as a proxy for indicative relevant employment per company for:

- NI registered companies which have not reported employees in their latest filed accounts
- Non-NI registered companies
- The largest NI-registered companies (which may have operations elsewhere).

3.27 For large companies with large non-software activities we have also applied the keyword 'software' as a further filter in deriving the indicative relevant employment from LinkedIn (this has been applied to Almac, BT, Capita, Citi, Danske Bank, Deloitte, EY, KPMG, Microsoft, PwC and Randox).

3.28 To run the clustering analysis we have developed a bespoke Python script, which uses an unsupervised machine learning technique called 'k-means clustering' to assign each company to one of a number of clusters, based purely on the textual similarities between the descriptions of their operations as given on their websites. The steps taken in this analysis are shown in the diagram below.

Figure 3-4: Company clustering analysis methodology

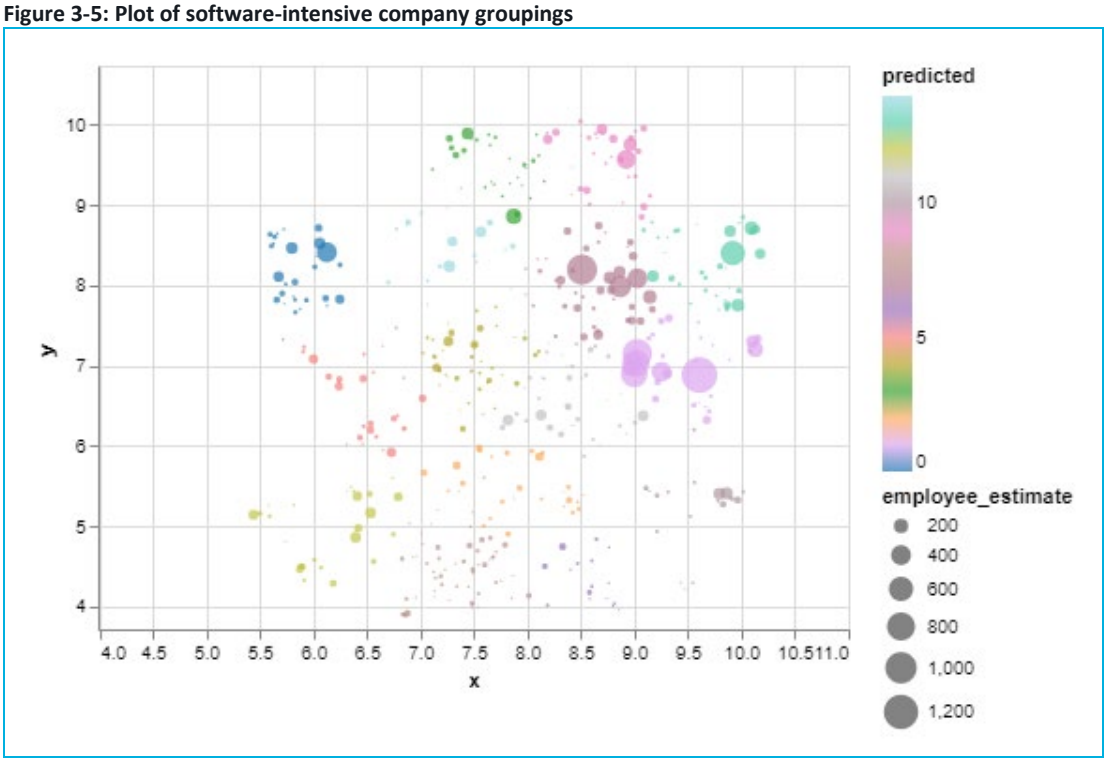


Source: DMS Research & Consulting

Results of Clustering Analysis

3.29 A plot resulting from this analysis is shown in the chart below, in which each of the companies is assigned to one of 15 groupings (separately coloured), visualised in two dimensions with the marker size being proportional to the indicative relevant employment in NI. The x and y axes in this chart are abstract dimensions derived from the UMAP dimensionality reduction algorithm, calculated such that companies with similar activities are visualised close together in two dimensions. The axes can be thought of as simplified summaries of the original data, distilling it into two aspects that capture the main patterns. The distances between points on the chart reflect their similarities in the original data, even though that data had many more details. Clusters, or groups of companies that are close together, indicate that these companies share common characteristics.

Figure 3-5: Plot of software-intensive company groupings



Source: DMS Research & Consulting

3.30 The charts in Annex C identify each of the 15 groupings and provide examples of companies predicted to be within that grouping by the k-means analysis, on the basis of similarities in their website text.

3.31 Note that this is not claimed to be the only or the 'right' way to group NI's software-intensive companies. In practice, many firms will undertake a wide range of activities which span across several sub-sectors and the grouping to which an individual business has been predicted to belong by the k-means algorithm (based on a snapshot sample of website text) may not always align with the business's own views of what sub-sector(s) it belongs to. The study's approach here is merely intended to provide a general impression of the relative 'weight' in NI's software economy of different areas, defined purely on the basis of similarities in a sample of the companies' website text.

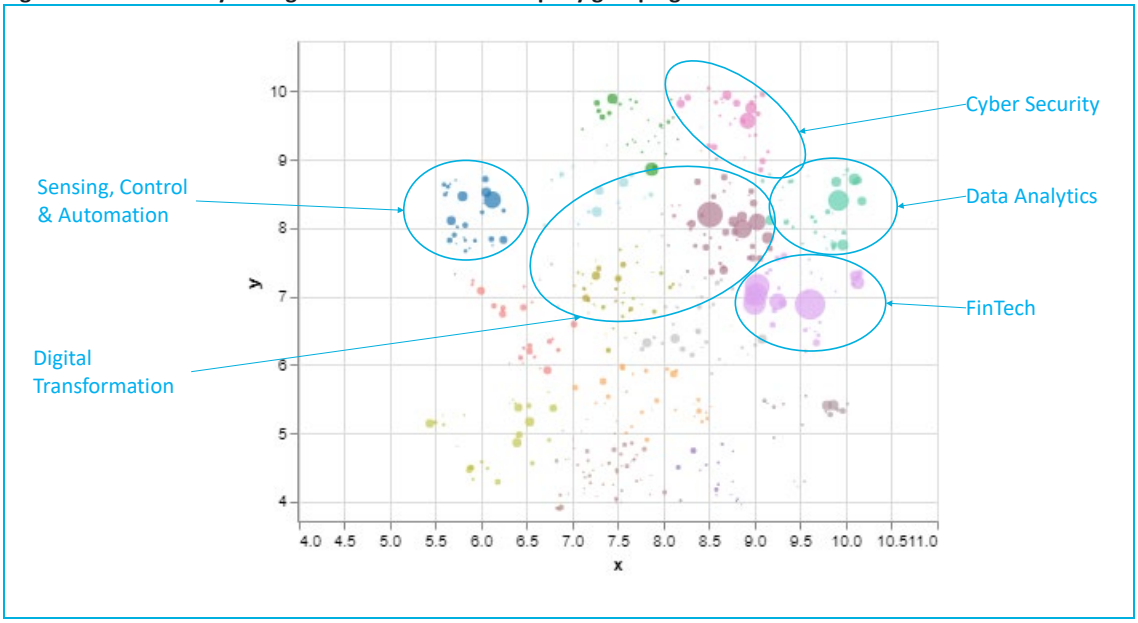
3.32 Note also that some groupings separated out by the k-means analysis of the website text could be considered more specialist subsets of wider groupings (e.g. Payment Tech as part of

FinTech), and there are three groupings identified which we consider to come under 'Digital Transformation').

3.33 The chart below highlights the sub-sectors in which NI is particularly strong on the basis of this analysis:

- **FinTech** (e.g. Allstate, FinTrU, Citi, FD Technologies, Liberty-IT);
- **Digital Transformation** (e.g. Kainos, Fujitsu, Version 1, Expleo, Telefonica Tech NI, Unosquare) ;
- **Cyber** (e.g. Rapid7, Proofpoint, Metacompliance, Imperva) ;
- **Data Analytics** (e.g. Seagate, Data Intellect, IBM, Diaceutics, Datactics, Analytics Engines); and
- **Sensing, Control & Automation** (e.g. Sensata, GE Grid Solutions, Johnson Controls, TES Group, FAST Technologies).

Figure 3-6: Particularly strong software-intensive company groupings in NI



Source: DMS Research & Consulting

3.34 The presence of a significant Data Analytics grouping may, on the face of it, appear to contradict the previous finding from LinkedIn and Adzuna that NI may be somewhat underweight in AI/Machine Learning and data science. However, the latter skills are widely distributed across sub-sectors (e.g. in FinTech, Cyber Security and Digital Transformation companies as well as the companies in the Data Analytics grouping), so the two findings are not inconsistent. NI has a significant grouping of Data Analytics companies, but – taken across the economy as a whole – has a lower proportion of people with AI/Machine Learning and data science skills than the UK average.

Summary of technology/specialism strengths and needs

- SIC 6201 (Computer programming activities) is an area in which NI has a genuine and significant specialisation.
- NI has done well in developing and attracting larger business sites in the field of software development, but is considerably underweight in terms of the presence of micro businesses in software-related areas.

- The share of total employment in software-related occupations is rather lower in NI than it is in GB excl London, but NI has a relative specialism in SOC 2134 (Programmers and software development professionals).
- Analysis of skills mentioned on LinkedIn and Adzuna suggests that NI is particularly strong in core software engineering skills such as C#, Java and JavaScript. However, mentions of AI, Machine Learning and Data Science look relatively low, and employment in these areas may be growing more rapidly elsewhere in the UK than they are in NI.
- Applying textual analysis and a k-means clustering technique to text scraped from software-intensive companies' websites, we see that the strongest areas of software-intensive specialism in NI are FinTech, Digital Transformation, Cyber, Data Analytics, and Sensing, Control & Automation.

4 Research and Innovation Capabilities

4.1 In this Section, we outline the research and innovation capabilities of NI's software economy in the business base and academia.

Key Messages

- There was total R&D expenditure of £210 million in NI's Information and Communications industries in 2019/20, amounting to 26% of all NI expenditure in HMRC's R&D tax credit dataset: a higher proportion than any other nation or region
- Numerous examples of innovation within NI's software-intensive businesses are complemented by a strong academic base. Ulster University ranked 9th out of 90 in REF 2021 for Research Power in Computer Science & Informatics, and 96% of Queen's University Belfast's Engineering submission[11] for REF 2021 was judged to be world-leading or internationally excellent
- In an analysis of Computer Science-related journal articles involving authors from QUB and UU since 2003, Artificial Intelligence, Security and Telecommunications stand out as the areas with the highest impact, and these are areas in which the universities are generally acknowledged to be particularly strong
- Both QUB and UU have spun-out successful software-related companies over the last few decades, most notably Kainos
- Examples of HEI-business collaboration include the universities' business support and incubator/accelerator programmes, Knowledge Transfer Partnerships, interactions on students' PhDs, industry sponsorship of post-docs, businesses using specialist equipment at university facilities, collaborative R&D projects, the AI Research Centre at UU and the forthcoming Cyber-AI Hub to be hosted at QUB
- Some businesses are actively collaborating in research with one or both of the universities and are complementary of their value, while others have had little recent interaction and don't see the research being undertaken at the universities as having particular relevance for them. In general, it appears that smaller businesses are finding harder to engage with the universities than is the case for larger businesses
- QUB's leading position in cyber research has contributed to developing a strong cyber sub-cluster within NI including many FDI firms. Both universities have strengths in Artificial Intelligence, which has a wide range of applicability across the software sector, including the strong areas of the business base in FinTech, Digital Transformation, Data Analytics, Cyber, and Sensing, Control & Automation

Business R&D

4.2 Many of the software-related activities in Northern Ireland's businesses can be classified as 'Research & Development' in that they are developing new or enhanced products and services, whether for external or internal customers.

4.3 R&D Tax Credit claim information from HMRC[12] reveals that in 2019/20, there was total R&D expenditure of £210 million in SIC section J (Information and Communications) in Northern Ireland[13]. This amounted to 26% of total R&D expenditure (across all sectors): a higher proportion than any other nation or region, as illustrated below. This emphasises the

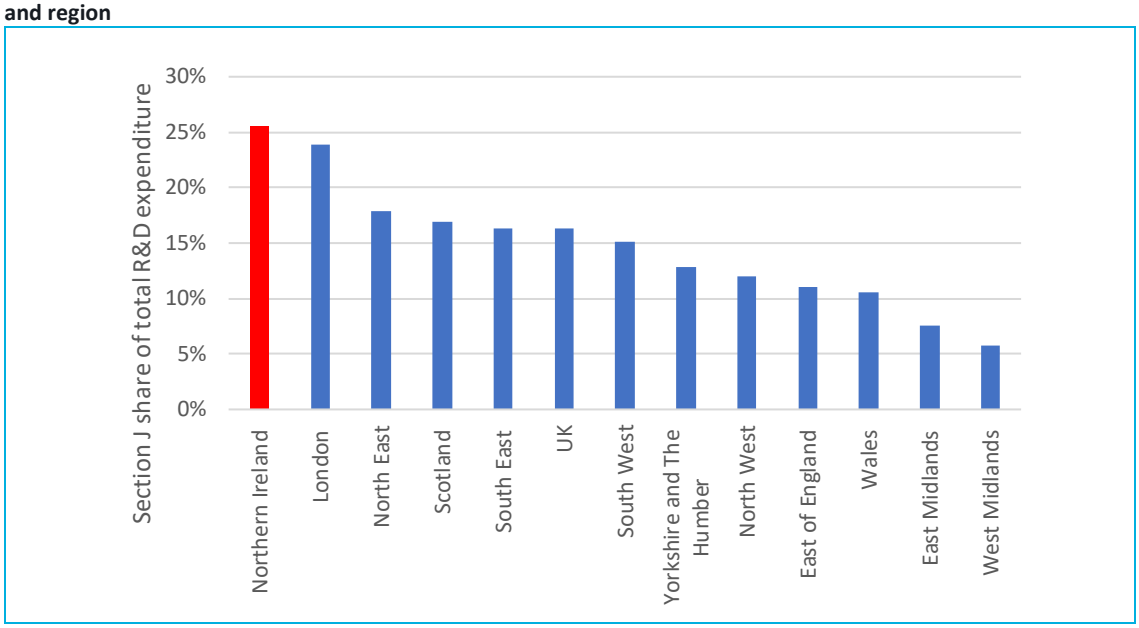
[11] QUB did not submit an entry for the Computer Science & Informatics Unit of Assessment (UoA) in REF 2021. However, computer science research was included in its submission for the Engineering UoA.

[12] Source: **Research and Development Tax Credits Statistics: Supplementary Tables 2021** , HMRC.

[13] Note that this refers to total qualifying R&D expenditure rather than the tax credit claimed. More detailed industry breakdowns are not available within nations and regions. However, at UK level, the most relevant 2-digit industry (SIC62: Computer programming, consultancy and related activities) accounted for 75% of total R&D expenditure in section J.

particularly important role of Northern Ireland's software-intensive industries in driving innovative activity in NI.

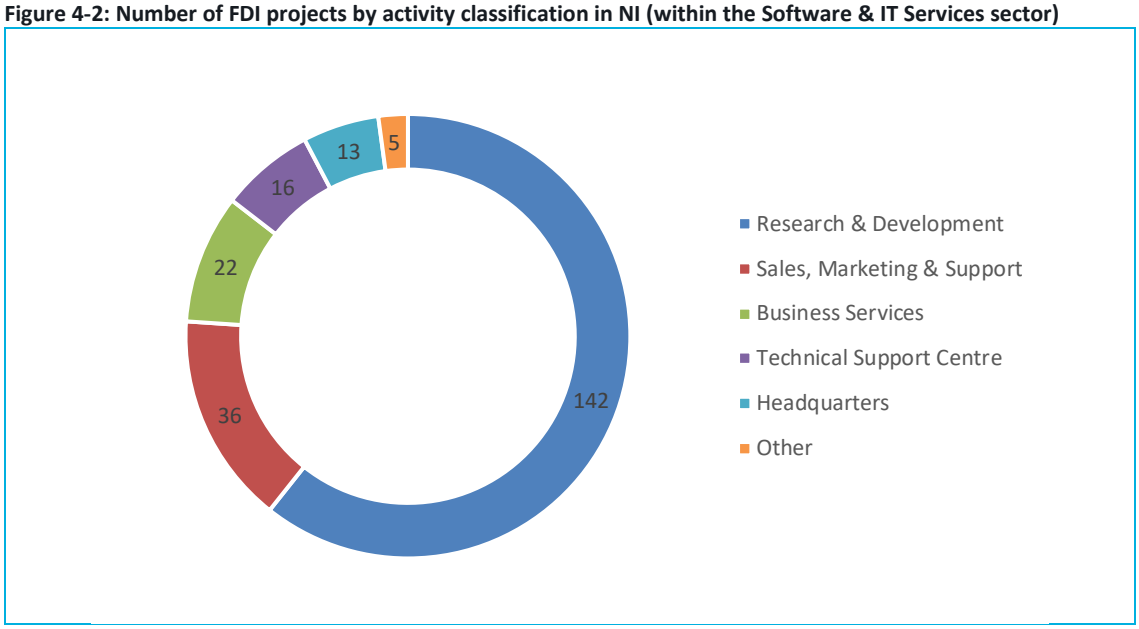
Figure 4-1: Information & Communications share of total R&D expenditure in R&D tax claims 2019-20, by nation and region



Source: HMRC R&D Tax Credit Statistics 2021

4.4 It is reasonable to assume that much of this R&D activity is undertaken in FDI firms' NI operations: most of the FDI projects in the Software and IT Services sector since 2003 were classed as Research and Development, according to fDi Markets (Figure 4-2).

Figure 4-2: Number of FDI projects by activity classification in NI (within the Software & IT Services sector)



Source: fDi Markets

4.5 A few examples of innovative activity undertaken within NI's software-intensive business base include[14]:

- **PlotBox**- developed the first purpose-built solution of its kind to integrate two previously separate functions: deathcare management software and geo-rectified mapping;
- **Axial3D** – has recently (January 2023) announced the launch of a new medical 3D Printing Centre of Excellence in Belfast powered by their cloud-based segmentation service which turns 2D medical images into patient-specific 3D models;
- **Liopa** – is commercialising over 10 years of research in the field of speech and image processing, with particular focus on the fusion of speech and lip movements for robust speech recognition in real-world environments;
- **Angoka** – focuses on cyber security for smart cities and smart mobility; its innovations include technology to integrate identity management and secure data communications for Unmanned Aerial Vehicles;
- **Kainos** – has helped public sector organisation transform their business processes; for example, working with HM Passport Office to transform the passport application process, resulting in applications taking less than 10 minutes on average;
- **Data Intellect** (formerly AquaQ Analytics) - developed the TorQ framework, which is a high-performance data ingestion and processing system used by many banks and hedge funds to collect market data into kdb+ databases;
- **See.Sense** - includes patented sensor technology within products such as bike lights, generating detailed insights into the rider's experience including swerving, braking, road surface condition and dwell times;
- **Neurovalens** - has designed cranial nerve stimulation technology that accurately and efficiently activates key brainstem neurons without needing implanted electrodes; applications include tackling anxiety, type 2 diabetes, insomnia and obesity; and
- **B-Secur** – has developed HeartKey 2.0, a suite of powerful electrocardiogram algorithms and analytics that enhances signal clarity, reduces signal noise, and delivers FDA-cleared health data with actionable wellness insights.

4.6 A number of consultees noted that various innovation activities are underway in the area of 'digital twins' – including the Digital Catapult's planned new national digital twin programme: the Design Smarter Digital Twin Centre in Belfast.

HEI Research

Queen's University Belfast

4.7 QUB has various research groups active in the area of computer science. In particular, the School of Electronics, Electrical Engineering and Computer Science incorporates the Institute of Electronics, Communications and Information Technology (ECIT). ECIT has three research centres:

- **Centre for Secure Information Technologies** (CSIT) brings together complementary research clusters to carry out research focused on market-informed grand challenge areas: Secure Connected Devices; Networked Security Systems; Industrial Control Systems (ICS) Security; and Security Intelligence;

[14] These software-intensive firms all appeared in the top ten of Northern Ireland's most innovative technology companies in BusinessCloud's **Northern Ireland Tech 50** for 2020

- **Centre for Wireless Innovation** (CWI) focuses on physical layer wireless: Future Cellular Systems; Electromagnetic Sensing; Green Wireless; Space Applications; Connected & Autonomous Systems; and Physical Layer Secure Wireless; and
- **Centre for Data Science and Scalable Computing** (DSSC): focuses on Machine Learning Solutions in Computer Vision, Spatio-Temporal Analytics, Record Linkage for multi-source data integration, Natural Language Processing and Brain Science, High Performance Computing, Fog/Edge Computing, Cloud Computing, and Dependable Energy Efficient Systems.

4.8 QUB did not submit an entry for the Computer Science & Informatics Unit of Assessment (UoA) in REF 2021. However, computer science research was included in its submission for the Engineering UoA, in which QUB ranked 19th out of 89 for Research Power[15]; 140 FTEs were entered and the overall GPA was 3.32, with 96% of the submission judged to be world-leading (36%) or internationally excellent (60%).

4.9 Examples of how QUB's computer science research strengths have translated into local, national or international impacts are given by impact case studies submitted by QUB for REF 2021:

Table 4-1: Computer science related impact case studies submitted by QUB for REF 2021

Title	Summary of impact
Acceleration of Big Data Applications	Research into software for accelerating signal and data processing solutions has spun out from Queen's University as Analytics Engines Ltd. Analytics Engines Ltd. has developed state-of the-art software that is applied across a diverse range of sectors. These include healthcare, trade, finance and digital infrastructure. Analytics Engines Ltd. has secured private investment of GBP[text removed for publication][16] and currently (2020) employs [text removed for publication] people. The company has created solutions used by over [text removed for publication] organisations, including The National Gallery London, and Innovate UK. The firm's solutions have allowed organisations to improve their data analytics capacity and to transform and modernise traditional processes.
Face Recognition for the Real World	AnyVision (revenue 2018/19 USD43,000,000) is the performance market leader in visual intelligence for the real world, having during 2016-2020 innovated new computer vision recognition technology surpassing human performance. AnyVision's system [based on QUB research], applied to standard, existing camera/computer installations, is more accurate, faster and less expensive than competitor systems which require controlled lighting/range and largely work on easy problems such as passport recognition. AnyVision's first commercial deployment in Europe's third largest airport, Schipol, with more than 200,000 people passing through it per day, and thousands more in the 'watchlist' generated only 1 false alarm. The system is currently deployed at multiple sites worldwide.

[15] Following the Times Higher Education methodology: Grade Point Average (GPA) is calculated by multiplying the % of 4* research by 4, the % of 3* research by 3, the % of 2* research by 2 and the % of 1* research by 1; those figures are added together and then divided by 100 to give a score between 0 and 4. Research Power is calculated by multiplying the institution's GPA by the total number of full-time equivalent staff submitted for that Unit of Assessment (UoA), reflecting the view that excellence is, to some extent, a function of scale as well as quality.

[16] The text in this table is taken verbatim from the REF 2021 results website – including '[text removed for publication]' where some details have been redacted

Title	Summary of impact
Hardware Accelerated Processor for Network and Cloud Security	Custom processors for high-performance pattern matching have been commercialised through QUB start-up, Titan IC Systems Ltd. which grew its revenue to over GBP1,200,000 at June 2019. These processors, used for malware and network intrusion detection have enabled hardware acceleration for products in the Cyber Defence and Enterprise Security markets. Titan IC's customers include cybersecurity, government and data analytics markets. Titan IC license product to three of the top five Network Interface Controller (NIC) vendors who together supply 50% of this market. Titan IC was acquired, in 2020, by the US company Mellanox a leading supplier of end-to-end Ethernet interconnect solutions.
Innovating High-Speed Network Processing of Future Internet and Cloud Services	Ever-increasing internet bandwidth is required to support streaming and real-time content, as well as growth in internet connected devices. This requires a new generation of Internet routers to provide quality of service and secure content delivery. Netronome, whose customers include the world's largest equipment vendors e.g. Dell, Cisco, is a world leader in high performance networking solutions. Netronome incorporated UoA research on high-performance management of internet traffic into its products, resolving the key challenge of tracking millions of simultaneous internet traffic flows. Netronome's turnover consequently increased by over GBP[text removed for publication] per year with customers experiencing latency reduction and increased capacity per server node.
Natural Disaster-Tolerant Wireless System that Saves Lives	A Catastrophe-Tolerant Heterogeneous Telecommunications Network, a resilient and agile wireless communications system, was designed and implemented by the UoA. This provides seamless connectivity to relief authorities and workers when telecommunications infrastructure is significantly impaired. Annually, central Vietnam is greatly affected by major storms that damage transportation, agriculture, and fishery, costing GBP1,900,000,000 in 2017. The Vietnam Disaster Management Authority and one of the three biggest Vietnamese mobile operators have incorporated the system into their national disaster response plans.
The Economic Impact of the Centre for Secure Information Technologies (CSIT)	The Centre for Secure Information Technologies (CSIT) is a national cybersecurity research institute emphasising research excellence combined with a unique model for, and focus on, commercialisation and innovation. CSIT is the UK's only Innovation and Knowledge Centre (IKC) for cybersecurity. CSIT played a key role in the development of major government reports on cybersecurity strategy and economic policy in the UK and EU. In addition, it has been instrumental in catalysing the development of the Northern Ireland Cybersecurity Ecosystem, DCMS programmes, start-ups, attracting FDI which had led by 2019 to the creation of approximately 1600 jobs in this sector.

Source: REF 2021 results website

Ulster University

4.10 UU conducts computer science research in four highly active research groups and centres:

- **Intelligent Systems Research Centre**: Developing fundamentally new AI algorithms in areas such as self-organising fuzzy neural networks, type-2 fuzzy logic systems, spiking neural networks, predictive modelling & analytics, computer vision, evolutionary algorithms, accelerated computing on FPGAs and bioinspired hardware self-repair.

- **Cognitive Analytics Research Lab** (CARL): Delivering world-class cognitive analytics research, building on UU's history of expertise in data analytics, in terms of machine learning algorithms and the application of analytical techniques across a diverse range of domains.
- **Artificial Intelligence Research Centre**: AIRC aims to develop cutting-edge AI theories, algorithms and tools, and to create state of the art AI solutions for practical problems through engagement with stakeholders and users.
- **Pervasive Computing Research Centre**: Focusing on multi-disciplinary and collaborative research in sensor-based technologies, and applications in behavioural analysis, activity recognition, and assistive technologies for healthcare and independent living.

4.11 UU ranked 9th of 90 in REF 2021 for Research Power in Computer Science & Informatics; 69.6 FTEs were entered and the overall Grade Point Average was 3.12, with 92% of the submission judged to be world-leading (20%) or internationally excellent (72%).

4.12 Examples of how UU's computer science research strengths have translated into local, national or international impacts are given by the impact case studies submitted by UU for REF 2021 for the Computer Science and Informatics unit of assessment (Table 4-2). These serve to demonstrate the particular strengths UU has in the area of digital health.

Table 4-2: Computer science related impact case studies submitted by UU for REF 2021

Title	Summary of impact
NeuroCONCISE: consciousness assessment in disorders of consciousness, enablement in spinal injury and growing the UK neurotechnology sector	Ulster has significantly improved patient outcomes, stimulated the UK neurotechnology sector and promoted knowledge exchange arising from the University's AI for brain-computer interface (BCI) research. Impacts include: I1 – establishing non-subjective evidence of consciousness in brain-injured patients with prolonged disorders of consciousness with specific beneficial, life-changing outcomes and leading to a national neurotechnology trial with 17 hospitals I2 – influencing two medico-legal High Court cases resulting in substantial compensation for brain-injured victims I3 – enabling a spinal-injured person to compete against other teams from around the world as a Cybathlete at Cybathlon 2016, 2019 (BCI series) and 2020 I4 – creation of a spinout company, NeuroCONCISE Ltd (Nov 2016), employing 5 people, to commercialise Ulster BCI research I5 – informing national reports that influenced the establishment of the KTN Neurotechnology Innovation Network and the UK roadmap for neurotechnology
Guiding life changing operations and rehabilitating stroke survivors through the Northern Ireland Functional Brain Mapping (NIFBM) facility – A unique facility for neuroscience	Ulster has impacted epilepsy and stroke patients, across the island of Ireland, via the Northern Ireland Functional Brain Mapping Facility. Impacts include: I1 – Epilepsy patients have been scanned and presurgical evaluation reports informed successful life-changing operations involving surgical brain resection at Beaumont Hospital, Dublin, Ireland. I2 – Change of clinical practice for presurgical evaluation of patients with refractory epilepsy in Northern Ireland and the Republic of Ireland (taking an all-island approach to Epilepsy Care and Treatment). I3 – Chronic post-stroke patients have achieved significant upper limb motor function recovery following brain-computer interface-driven hand exoskeleton rehab therapy over multiple sessions.

Title	Summary of impact
across the island of Ireland	
Digital health technologies in mental health sciences - using machine learning to enhance service design and delivery to people with mental health problems, people in suicidal crisis and people living with dementia	The impacts described in this case study include changes in policy and practice across several organisations as a result of the insights produced by novel application of machine learning to their data, including: I1 – Improved caller management for major national helplines from crisis helpline analysis research; I2 – Major digitalisation of assistance programmes for employees and vulnerable groups from mental health chatbot research; and I3 – National NHS reminiscence app from reminiscence research (the recollection of past events particularly important to support the memory of people with dementia) for people with dementia and their carers.
The translation of digital reminding solutions into connected health products for caregivers	Ulster's research in reminding solutions has contributed novel findings in medication management workflow, mobile-based video reminders for people with dementia and online training platforms for caregivers. This research underpins the following impacts: I1 – Internet based product for managing the logging and dispensing of medication leading to 8 jobs, uptake by 150 users across 5 care homes and annual revenue of GBP1,200,000. I2 – Online training platform for carers of people with dementia with 80 individual licences and 13 group sales in 6 EU countries. I3 – Establishment of new policy guidelines for 45,000 Social Care Council staff in Northern Ireland and impacting the life and health sciences sector in Northern Ireland.
Computational Cardiology Impacting on Medical Devices, Safer Drug Trials, Medical Training and Technical Standards	Ulster research on electrocardiography (ECG), which is used to detect cardiovascular disease (leading cause of death worldwide) resulted in the following impacts: I1 – an ECG algorithm that has been used by the FDA [text removed for publication] to monitor the risk of drug-induced abnormal heart rhythms, I2 – an interactive ECG recording simulator that was integrated into a medical textbook selling [text removed for publication], 2014-2019) I3/I4 – research on automated cardiac defibrillation resulted in the [text removed for publication] and the approval of a new AED which has been used to save lives. Informing working standards/reports (IEC 80601-2-86, IEEE P7003).
Technologies for Self-Management in Healthcare	Ulster's research on digital solutions for self-management of health conditions led to novel software architectures, communications infrastructure, sensing technologies and eHealth apps, resulting in a number of impacts including: I1 Establishment of a free-to-use, national, IoT communications platform (LPWAN-NI) accessed by >130 companies to develop approximately 19 products/services. I2 Development of an open software infrastructure to underpin the collection of sensor data for self-management solutions in Northern Ireland and Italy.

Title	Summary of impact
	I3 Creation of a self-management product, incorporating behaviour change strategies, for an SME in Northern Ireland, currently being sold in 22 countries.

Source: REF 2021 results website

Academic Journal Article Analysis

Method

4.13 To explore areas in which Northern Ireland's universities have relevant specialisms, the study undertook a basic bibliometric analysis using the recently launched open data source **OpenAlex**[17]. This indexes over 240 million scholarly works, adding about 50,000 daily, and its metadata includes authors, authors' institutions, publication dates, work titles, work abstracts, and citations. Access to the 'n-grams' used in the full text[18] of each work is also available for a subset of the database, using data from the **Internet Archive's General Index**.

4.14 OpenAlex also applies an automated classifier algorithm to assign 'concepts' to each work in the database, indicating what topics the work is about on the basis of its title, abstract and the 'host venue' (e.g. journal name). About 87% of works have been assigned at least one concept, and most have been tagged with multiple concepts. There are 19 root level (Level 0) concepts of which Computer Science is one, and a total of about 65,000 concepts in total under a tree-like hierarchy. Below Computer Science there are 32 'Level 1' concepts (and many more at lower levels); these include, for example, 'algorithm', 'data science', 'software engineering' , 'database' and 'computer security'.

4.15 The study used the OpenAlex API to extract metadata (including abstract text and citation count) for c. 5,400 journal articles which have been published since 1 January 2013, and which:

- Involved authors associated with Queen's University Belfast or Ulster University; and
- Are tagged by OpenAlex with one or more 'Computer Science' concepts at Level 0 or 1.

4.16 Analysing this data, we have looked at the count of articles over the period and the total citations for works tagged with each Level 1 concept. We have also applied a k-means clustering analysis to articles' full text (similar to the approach used above for companies' website text), in order to identify groupings of topics beyond those identified through OpenAlex's concept tagging.

Results by OpenAlex concept

4.17 Figure 4-3 below illustrates the relative 'weight' of each of the Level 1 concepts used by OpenAlex amongst the journal articles analysed, in terms of the total number of articles (x -axis) and the total citations for works tagged with that concept (y-axis). Note that logarithmic axes have been used to make this chart legible.

4.18 'Artificial Intelligence', 'Computer Security' and 'Telecommunications' stand out as the areas with the highest impact (as measured by the citations for journal articles tagged with those

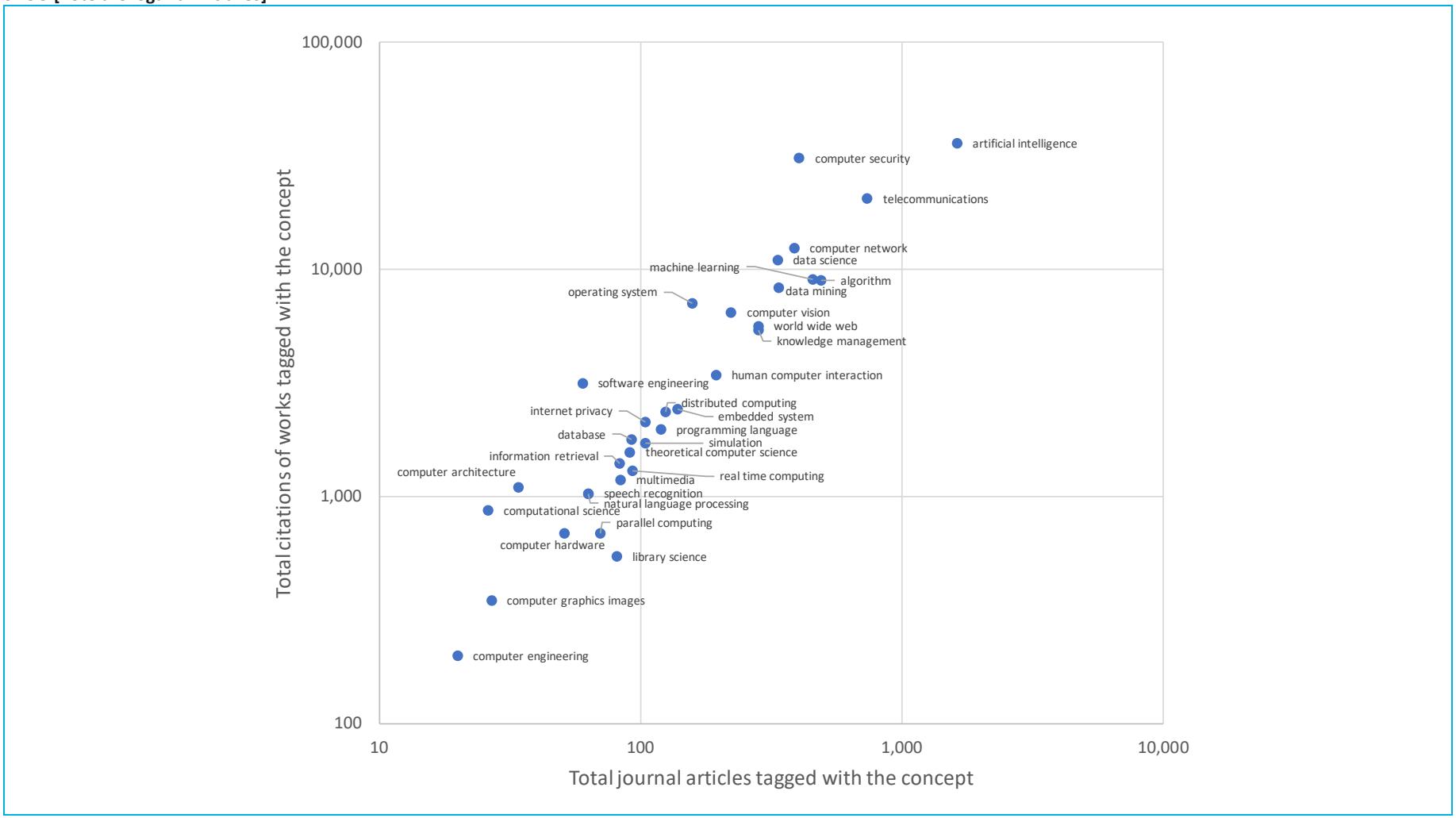
[17] See Priem, J., Piwowar, H., & Orr, R. (2022). *OpenAlex: A fully-open index of scholarly works, authors, venues, institutions, and concepts*. ArXiv. https://arxiv.org/abs/2205.01833

[18] N-grams list the words and phrases that occur in the full text of a work

concepts); and these are areas in which the two universities are generally acknowledged to be particularly strong.

4.19 Unsurprisingly there is a close relationship between the total count of articles and the total citation count per concept. However, note that some areas have considerably more citations than the overall average of 26 per work. In particular, 'Computer Security' (average of 76 citations per work), 'Operating System' (45), and 'Software Engineering' (52) articles seem to have had more impact than might be expected for their article count.

Figure 4-3: Total journal articles tagged with the concept versus total citations of works tagged with the concept, for works published since January 2013 involving authors from QUB or UU [note the logarithmic axes]



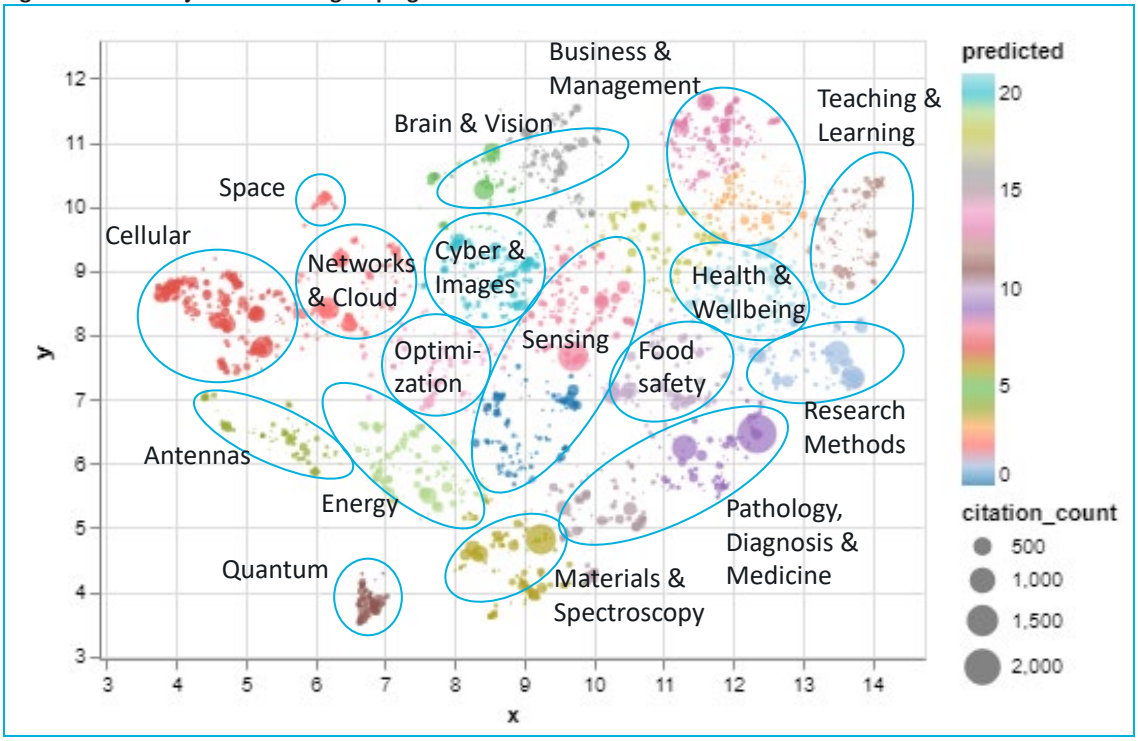
Source: DMS Research & Consulting analysis of OpenAlex data, February 2023

Results of Clustering Analysis

4.20 The chart below plots the 3,204 journal articles for which full-text n-grams are available. Each of the journal articles is assigned to one of 22 groupings (separately coloured), visualised in two dimensions with the marker size being proportional to the citation count for the work. Note that, as OpenAlex is reliant on the Internet Archive for the full text n-gram data, more recent papers are likely to be under-represented in this sample.

4.21 Informed by the paper titles within each of the k-means groupings we have also highlighted the broad areas of research that appear to be most prevalent in those clusters. The clustering analysis of these works demonstrates the broad range of topic areas to which computer science-related research and methods are being applied: from Cellular, Antennas, Networks & Cloud, Quantum and Cyber to Energy, Sensing, Food Safety, Health & Wellbeing, and Pathology, Diagnosis & Medicine.

Figure 4-4: Plot of journal article groupings



Source: DMS Research & Consulting analysis of OpenAlex data, February 2023

HEI Spin-Outs

4.22 Both QUB and UU have spun-out successful software-related companies over the last few decades, with Kainos[19] being the outstanding example. See Table 4-3 and Table 4-4, which include information on how many worldwide employees were listed on LinkedIn as of May 2023, to give a broad indication of current company size.

[19] Kainos was originally established as a joint venture between QUB's commercialisation arm QUBIS and ICL [source: Kainos website]

Table 4-3: Software-related spin-outs from QUB

Company	Activity	Year founded	Employees on LinkedIn, May 2023
Kainos	Digital transformation	1986	2,777
Andor Technology	Scientific cameras, microscopy systems & spectrographs	1989	335
EventMAP	Optimising planning, scheduling and resource management	2002	39
Titan IC Systems (now part of Nvidia)	Cyber security analytics acceleration and content processing	2007	31
Cirdan Imaging	Innovative software and imaging solutions for the acceleration and enhancement of diagnosis	2010	82
Adoreboard	SaaS platform to predict drivers of customer and employee satisfaction	2011	20
Analytics Engines	Data integration, data management, machine learning, AI, advanced analytics and visualisations	2014	26
Liopa	Automated, AI-based lipreading to assist with speech recognition and voice technologies	2016	9
Sonrai Analytics	AI data discovery solution for biomarker discovery, development and deployment	2018	32

Source: QUB website, company websites and LinkedIn, May 2023

Table 4-4: Software-related spin-outs from UU

Company	Activity	Year founded	Employees on LinkedIn, May 2023
Datactics	Data quality and matching software to help customers tap into their data assets	1999	79
Intelesens	Specialist manufacturer of defibrillator and ECG electrodes	2000	9
Performa Sports	Real-time sports performance analysis tool designed for analysts, coaches and players	2010	4
Axial3D	Transforming 2D medical image data into 3D for surgeons and medical device manufacturers	2014	57
NeuroCONCISE	Wearable neurotechnology for brainwave measurement and analysis	2016	5

Source: UU website, company websites and LinkedIn, May 2023

HEI-Business Collaborations

4.23 Both QUB and UU have engaged local employers (particularly larger businesses) to help steer the development of their computing curricula. However, the study's consultations revealed a **rather patchy picture regarding collaboration between NI's software businesses and NI's**

universities on research & development (as opposed to student education and placements). Some businesses are actively collaborating in research with one or both of the universities, and complementary of their value, while others have had little recent interaction and don't see the research being undertaken at the universities as having particular relevance for them. In general, it appears that **smaller businesses are finding harder to engage with the universities** than is the case for larger businesses.

4.24 Examples of HEI-business collaboration mentioned by consultees include:

- The universities' **business support and incubator/accelerator programmes**, such as LORCA at QUB and 'research pitstops' with businesses at UU;
- **Knowledge Transfer Partnerships**, in which a graduate or post-graduate is taken on by a business to lead a project with support from the business and the university (used by several of the study's business consultees);
- Interactions on students' **PhD projects**;
- Industry sponsorship of **post-docs**;
- Businesses using **specialist equipment** at university facilities;
- Large **collaborative R&D projects** such as the **£5.4 million project** between QUB and Nvidia to explore research challenges around AI-centric cloud and data centre security
- The **AI Research Centre** at UU, sponsored by Kainos; and
- The forthcoming £10.4 million **Cyber-AI Hub**, to be hosted at QUB, involving eight companies.

4.25 In terms of the alignment between NI's universities' research strengths in computer science and the areas of NI's software business base which are particularly strong, the **clearest alignment is in cyber** security – with QUB's leading position in cyber research having contributed to developing a strong cyber sub-cluster within NI including many FDI firms.

4.26 In **digital health & wellbeing** there are particular research strengths at UU (see, for example the impact case studies in Table 4-2) and there is increasing business activity in this area in NI, albeit not yet on the scale of FinTech, Digital Transformation or Cyber.

4.27 More significantly, both universities have research strengths in **Artificial Intelligence**, which has a wide range of applicability across the software sector, including the strong areas of the business base in **FinTech**, **Digital Transformation**, **Data Analytics**, **Cyber**, and **Sensing, Control & Automation**.

5 Assessment of Growth Prospects and 'Windows of Opportunity'

Key Messages

- The study's review of industry reports and the stakeholder consultations indicate that there continues to be very healthy growth prospects for software-intensive areas in which NI is particularly strong: FinTech, Digital Transformation and Cyber
- However, the research also highlights three 'megatrends' which are seen as being critically important throughout NI's software sector, but which are also areas where NI needs to grow its capacity and capabilities to remain globally competitive:
  - Artificial intelligence;
  - Data science and data engineering; and
  - Cloud.
- NI has a 'window of opportunity' over the next five years or so to strengthen its capabilities in these areas. If it fails to do so, there is a real risk of falling further behind competing locations, with adverse consequences for the growth of NI's software economy

Global Software Market

5.1 NI's software sector operates in a **global market which is both very large and rapidly growing**. According to the latest forecast by Gartner[20], global expenditure on software is expected to grow by 9.3% in 2023, to reach $856 billion p.a. More specifically, for the areas in which NI is particularly strong (FinTech, Digital Transformation and Cyber) industry projections are suggesting continued strong growth. For example:

- Technavio[21] estimates that the **financial service application** market to grow to $119 billion by 2027, at a compound annual growth rate of 7.85% over the period 2022 to 2027. The market's progress is influenced by various factors, such as the rise in government campaigns to digitise the financial sector, the benefits of digital payment, and a surge in FinTech expenditure;
- International Data Corporation (IDC) estimates[22] that the revenue generated by **enterprise applications** across the globe will expand from $279.6 billion in 2022 to $385.2 billion in 2026, at a compound annual growth rate of 8%. Most of this expansion is anticipated to result from the allocation of funds towards public cloud software, which is estimated to contribute to almost 66% of the entire enterprise applications revenue in 2026 and

[20] Source: *Gartner Forecasts Worldwide IT Spending to Grow 2.4% in 2023*, Gartner, January 2023

[21] Source: *Financial Service Application Market by End-user, Deployment, and Geography - Forecast and Analysis 2023-2027*, Technavio, February 2023

[22] Source: *IDC Forecasts Steady Growth for Enterprise Applications through 2026 in Support of Digital Business Objectives*, IDC, January 2023

- According to the Worldwide Security Spending Guide[23] released by IDC, the global expenditure on **security** solutions and services is predicted to rise to $219 billion in 2023: a growth of 12.1% from 2022. The continuous threat of cyberattacks, the obligation to ensure a secure hybrid work atmosphere, and the necessity to comply with data privacy and governance standards are likely to boost investments in cybersecurity hardware, software, and services to almost $300 billion in 2026.

Key Trends Identified in Industry Reports

5.2 To highlight global trends that will be shaping the software industry over coming years, the following sub-sections summarise the key technology trends identified in recent reports from a selection of leading industry analysts:

- **Gartner Top 10 Strategic Technology Trends for 2023**, Gartner, October 2022;
- **The Top 10 Emerging Technologies In 2022**, Forrester, September 2022;
- **Tech Trends 2023**, Deloitte, 2023; and
- **McKinsey Technology Trends Outlook 2022**, McKinsey, August 2022.

Top 10 Strategic Technology Trends for 2023, Gartner

5.3 Gartner expects the 2023 key technology trends to impact enterprise strategies in the coming three years by enabling organisations to address the study's key priorities:

- **Optimising** resilience, operations or trust;
- **Scale** productivity and customer value by advancing solutions, product delivery and connectivity;
- **Pioneering** customer engagement, accelerated responses or opportunity, and
- Pursuing sustainable technology solutions.

Optimise

- **Digital Immune System** creates an enhanced customer experience by combining multiple software engineering strategies to protect against risk;
- **Applied Observability** works from the data emitted by an organisation, using AI to analyse and make recommendations, which allow an enterprise to make faster and more accurate future decisions; and
- **AI TRiSM** supports AI model governance, trustworthiness, fairness, reliability, robustness, efficacy and data protection.

Scale

- **Industry Cloud Platforms** combine Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) with tailored, industry-specific functionality that organisations can use to more easily adapt to the relentless stream of disruptions in their industry;
- **Platform Engineering** provides a curated set of tools, capabilities and processes that are packaged for easy consumption by developers and end users; and
- **Wireless-Value Realisation** covers the provision of wireless network services from everything, including traditional end-user computing, support for edge devices, digital tagging solutions, etc.

[23] Source: *Worldwide Security Spending Guide*, IDC, March 2023

Pioneer

- **Superapps** combine the features of an app, a platform and an ecosystem in one application, providing a platform for third parties to develop and publish their own miniapps on;
- **Adaptive AI** allows for model behaviour change post-deployment by using real-time feedback, to continuously retrain models and learn within runtime and development environments, based on new data and adjusted goals, to adapt quickly to changing real-world circumstances; and
- **Metaverse** allows people to replicate or enhance their physical activities. This could happen by transporting or extending physical activities to a virtual world or by transforming the physical one.

Sustainable Technology

- **Sustainable technology** is a framework of solutions that increases the energy and efficiency of IT services; enables enterprise sustainability through technologies like traceability, analytics, emissions management software and AI; and helps customers achieve their own sustainability objectives. Investments in sustainable technology also have the potential to create greater operational resiliency and financial performance, while providing new avenues for growth.

The Top 10 Emerging Technologies In 2022, Forrester

5.4 Forrester's list of emerging technologies is organised by how quickly organisations can expect to secure positive returns on investment (RoI) from them:

Short-Term RoI

- **Cloud-Native Computing** - The RoI of cloud-native computing comes from fast development cycles that increase an organisation's ability to react quickly to changing market conditions—while quickly rolling out the new features and functionality customers demand. That's why the RoI from cloud-native computing can be so quickly realised; and
- **Natural Language Processing (NLP) -** NLP is another rapidly maturing technology that is showing near-term positive RoI. Forrester defines NLP as *'the diverse set of technologies and practices that enable the ingestion, processing, understanding, and generation of natural human language'* in artificial intelligence applications across AI applications. Marketing and financial services are likely NLP's biggest near-term beneficiaries, because NLP helps create more customisable and convenient customer experiences at scale.

Longer-Term RoI

- **Edge Intelligence** - Edge intelligence is the capability of capturing more data from edge devices, applications, and users to improve real-time insights and intelligence. The technologies involved include streaming analytics, edge machine learning, real-time data management on intelligent devices, and edge servers. Edge-intelligence use cases include distributed data fabrics, Internet of Things (IoT) networks, smart homes and cities, and digital twins;
- **Explainable AI** - Explainable AI, as Forrester defines it, is a collection of processes and techniques designed to ensure that people understand AI systems. Specifically, XAI works by building a surrogate of an AI model that approximates its inner workings. According to the report, it increases trust by allowing humans to understand what is going on behind the scenes of an AI process. This understanding is thought to increase trust;
- **Intelligent Agents (IAs**) - The goal of IA is to improve customer experience by triggering events as directed by a human (for instance, the way Amazon's Alexa and Apple's Siri do)

or automatically. This tech is slow-growing given that many of the technologies involved—such as AI, NLP, RPA, chatbots, etc.—are still maturing, according to the report, and

- **Privacy-Preserving Technologies** - The report outlines that privacy-preserving technologies (PPTs) include technologies such as privacy filtering for accessing personal data, security controls for data processing and use, and controls to secure the environment where data processing happens.

Questionable Long-Term RoI

- **Extended Reality** - Forrester defines extended reality *'as technology that overlays computer imagery over a person's field of vision to create a new understanding of physical reality.'* It is being used in real-world scenarios such as helping remote field workers do their jobs better and training technicians on the factory floor. In general, however, use cases outside of gaming and higher education are limited, according to the report; so too with the availability of suitable hardware;
- **Web3** - Forrester defines Web3 as *'a concept that promises a World Wide Web that isn't dominated by big tech or other established firms, like banks.'* This decentralised, egalitarian vision of the Internet is many years away, however; Web3 is still in the development and experimentation stage; and
- **Turing Bots** - Forrester defines Turing bots as *'AI-powered software that can help and augment developers and their teams' intelligence and ability to design, build, change, test and refactor software code and applications in automatic and autonomous ways.'* Turing bots are designed to take over code testing and the other mundane, rote work of building software from unified modelling language (UML) code samples through to a wireframe of the applications.

Tech Trends 2023, Deloitte

5.5 Six key technology trends are identified by Deloitte:

- **Immersive Internet** - Technologies such as augmented and virtual reality are transforming the metaverse from specialised tech to enterprise tool—potentially paving the way for new business models. This could lead to sensory expansion (e.g. smelling and tasting through the metaverse), thought based control (e.g. control of digital environments through thought), and special interaction (walking up to a restaurant and seeing deals and prices);
- **Trusting AI** - While the value of artificial intelligence is now undoubtable, the question has become how to best use it—and that often boils down to how much workers and end users trust AI tools. Developing processes that leverage AI in transparent and explainable ways will be key to spurring adoption;
- **Multicloud Management** - To simplify multicloud management, enterprises are beginning to turn to a layer of abstraction and automation that offers a single pane of control. With an extra layer of abstraction and automation between the various cloud platforms, organisations don't need as much specialisation in their workforce. Instead of specialising in specific cloud platforms, cloud developers can build more general skills;
- **Reimagining the Tech Workforce** - Organisations have been competing for a limited supply of tech talent. A winning long-term strategy instead creates, curates, and cultivates new talent. Organisations that want to protect and pursue their transformation projects require a strategy-driven, differentiated approach to finding staff. Those who meet their talent goals will likely expand their conception of how technology work is planned and executed, instead of over-fitting for current technical needs;

- **Decentralised architectures and ecosystems** - In an environment of ever-increasing mistrust, blockchain and Web3 could power 'trustless' systems that decentralise data to rebuild trust. Decentralised systems, applications, and business models add a protective layer to the existing transaction infrastructure, enabling organisations to close the digital trust gap; and
- **Mainframe modernisation** - Instead of completely replacing mainframe systems, businesses have begun looking for ways to extend the functionality of mainframe systems by linking them to emerging technologies.

Technology Trends Outlook 2022, McKinsey and Co

5.6 The 14 technology trends highlighted in this McKinsey report are:

- **Advanced Connectivity** - 5G/6G cellular, wireless low-power networks, low-Earth-orbit satellites, and other technologies support a host of digital solutions that can help networks increase geographic coverage, reduce latency, reduce energy consumption, increase data throughput, and increase spectrum efficiency. This has led to higher-quality network access for consumers and unlocked new use cases for industrial players;
- **Applied AI** - Applied AI uses intelligent application to solve classification, prediction, and control problems to automate, add, or augment real-world business use cases. As AI technologies rapidly push new frontiers of innovation, business adoption continues to grow across use cases;
- **Cloud and edge computing** - Networks of the future consist of traditional cloud data centres and a variety of computational resources located at network edge nodes closer to end users to reap the benefits of traditional cloud computing while gaining advantages such as better data latency and increased data autonomy;
- **Immersive-reality technologies** - The immersive-reality space has four key components – spatial computing, mixed reality, augmented reality, and virtual reality. Immersive-reality technologies will have a significant role to play in the metaverse
- **Industrialising machine learning** - Machine learning (ML) workflows are the processes that bring AI and ML into production for real-world business use. Solutions industrialising ML provide the software and hardware technologies to scale ML workflows and ease the development and deployment of ML for organisations;
- **Next generation software development** - The next generation of software development involves tooling that aids in the development of software applications, improving processes and software quality across each stage of the software development life cycle, including AI-enabled development and testing, as well as low-code/no-code tools;
- **Quantum technologies**:
  - Quantum computing uses quantum properties of particles to process information at a much higher rate than a classical computer can. For some computational problems, quantum technology could make computation much faster than with classical computers;
  - Quantum communication is the transfer of encoded quantum information between distant locations based on an optical fibre network or satellites. A central feature is the quantum-secure connection through quantum encryption; and
  - Quantum sensing could provide measurements of various physical quantities at a sensitivity that is orders of magnitude higher than classical sensors can achieve. Applications include radar, microscopy, and magnetometers.
- **Trust architectures and digital identity** - Increasing cyberattacks and data breaches continually pose new challenges by leveraging trending technology (e.g. quantum

computing for encryption breaking). Digital-trust technologies empower organisations to gain a competitive advantage by building, scaling, and maintaining the trust of stakeholders (e.g. customers and regulators) in the use of their data and digital-enabled products and services;

- **Web3** - Web3 includes platforms and applications that enable shifts toward a future, decentralised internet with open standards and protocols while protecting digital ownership rights, providing users greater data ownership and control over how their data is monetised, and catalysing new business models;
- **Future of bioengineering** - From the cellular level to complex living systems, the future of bioengineering reflects the convergence of biological and information technologies to transform business and society. It is defined by four arenas: biomolecules, biosystems, biomachine interfaces, and biocomputing; in recent years, biomolecules and biosystems have experienced widespread developments, and there are significant opportunities software-intensive businesses;
- **Future of clean energy** - The clean-energy future is a trend toward energy solutions that help achieve net-zero emissions across the energy value chain, from power generation or production to storage to distribution. Computing hardware platforms and software are going to need to be still more energy efficient going forward;
- **Future of mobility** - Mobility is undergoing its 'second great inflection point'—a shift toward autonomous, connected, electric, and smart (ACES) technologies, in which software platforms will clearly be vital. This shift promises to disrupt markets while improving efficiency and sustainability of land and air transportation of people and goods;
- **Future of space technologies** - Technological advancements and the reduction of size, weight, and power of satellites and launch vehicles have contributed to cost-effectiveness, making new space applications more economically feasible; and
- **Future of sustainable consumption** - Sustainable consumption centres on the use of goods and services that are produced with minimal environmental impact, using low-carbon and sustainable materials. Enabling technologies transform industrial and individual consumption to address environmental risks, including climate change.

ChatGPT

5.7 The study team has also used a Large Language Model AI tool to summarise key market trends, based on the massive corpus of internet text on which it has been trained. ChatGPT was asked: *'What will be the most important trends in software over the next 10 years?'*. Its response was both remarkably credible and in line with the areas commonly cited in the above industry analyst reports and in the study's stakeholder consultations:

"Predicting the exact trends in software over the next 10 years is challenging, as technology is constantly evolving. However, based on current advancements and emerging technologies, here are some potential important trends that may shape the software industry in the coming years:

- ***Artificial Intelligence (AI) and Machine Learning (ML):** AI and ML technologies will continue to advance, enabling software to become more intelligent, automated, and capable of making data-driven decisions. This includes applications in various fields such as natural language processing, computer vision, autonomous systems, predictive analytics, and personalized user experiences;*
- ***Internet of Things** (IoT): The proliferation of IoT devices will create a massive network of interconnected devices, generating a vast amount of data. Software will play a crucial role*

in managing, analyzing, and extracting value from this data, enabling smart cities, smart homes, industrial automation, and improved efficiency in various sectors;

- ***Cloud Computing**: Cloud computing will continue to expand its influence, offering scalable and cost-effective solutions for software development, deployment, and storage. The adoption of cloud platforms, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), will likely increase, enabling flexible and accessible software solutions;*
- ***Cybersecurity**: As technology advances, the need for robust cybersecurity measures becomes increasingly critical. Software will need to incorporate advanced security features to protect against evolving threats such as data breaches, ransomware, and AI-powered attacks. This includes the development of secure coding practices, encryption, biometrics, and improved authentication mechanisms;*
- ***Low-Code/No-Code Development**: The demand for software solutions is growing rapidly, and not all organizations have the resources or technical expertise for traditional software development. Low-code/no-code development platforms will gain popularity, enabling users to build software applications with minimal coding knowledge. This democratization of software development will accelerate innovation and empower citizen developers;*
- ***Quantum Computing**: While still in its early stages, quantum computing has the potential to revolutionize software development by solving complex problems that are currently intractable for classical computers. As quantum technology progresses, software engineers will need to adapt and develop algorithms and applications specifically designed for quantum computers;*
- ***Blockchain and Distributed Ledger Technology** (DLT): Blockchain and DLT offer transparent, secure, and decentralized solutions for various industries beyond cryptocurrencies. The adoption of blockchain in areas like supply chain management, healthcare, finance, and identity verification will continue to grow, requiring software developers to create applications that leverage these technologies; and*
- ***Augmented Reality (AR) and Virtual Reality (VR):** AR and VR technologies are gaining traction, transforming user experiences in gaming, entertainment, education, training, and remote collaboration. Software will play a crucial role in creating immersive and interactive environments, requiring developers skilled in AR/VR frameworks and tools."*

Key Trends Noted in Stakeholder Consultations

5.8 In the study's fieldwork consultations (see Annex B), the key market trends cited most frequently by interviewees as being relevant to the NI software economy were:

- **Artificial intelligence**. Developments in the cloud and processing technologies have supported enormous recent progress in AI, including generative AI such as ChatGPT. AI is increasingly being applied throughout the software sector and across all industry sectors. Developing AI capabilities is seen as critical to future success. Consultee comments included: *'A good understanding of AI will define the winners and losers over the next five years'* and *'Every major breakthrough in the next five years will come from AI'*;
- **Big data**. Private sector and public sector organisations are increasingly drawing on big data to gain insights and competitive advantage which drive productivity growth – including through applying AI techniques. Businesses across all sectors will need data scientists to analyse these datasets, and data engineers to implement and maintain the data in the production environment;
- **Cloud**. Organisations continue to shift their software applications to run on cloud infrastructure rather than their own servers. This provides improved scalability, reliability,

security and energy efficiency. Nowadays most new software solutions will be developed and deployed on the cloud, and the industry needs people with experience of developing software for deployment on platforms such as AWS, GCP and Azure;

- **Digital transformation and automation**. Organisations continue to drive improvements in productivity and in the customer experience through intelligent automation of their business processes – minimising the work required from humans on routine and repetitive tasks, and freeing up staff to focus on more complex decision-making; and
- **Cyber security**. Cyber threats from criminals and hostile states will continue to increase. AI will be an important tool in helping to identify and tackle these threats, but it will also be used by bad actors.

5.9 Multiple consultees also identified the following as important trends for the software sector, including both societal and technological trends:

- **Climate change and net zero**. Software products and services to help address the net zero challenge will be increasingly important; and with the escalating processing power associated with large Machine Learning models there will be growing pressure to reduce the energy consumed by computers. There is an increasing focus on 'green software' practices[24]: creating software that operates with reduced energy consumption, reduced carbon emissions and reduced environmental impact;
- **Ageing population and digital health**. As populations age around the world and pressures increase on health and social care services, there will be growing demand for software solutions to help make health and social care more effective and efficient;
- **Remote working**. The shift to remote working accelerated by pandemic lockdowns has brought increased acceptance of online meetings and online delivery of services which would previously have been delivered face-to-face, such as training. It has increased the pool of labour from which NI software businesses can recruit, but has also meant that NI people can be recruited by businesses outside of NI, creating more competition in the sector;
- **Low code/no code**. Solutions which enable business users to implement and amend customised workflows, without help from specialist software developers, will become increasingly popular;
- **Quantum computing**. Although seen as being a few years away from mainstream market-readiness, the increased processing power of quantum computing will have an important impact, and presents new challenges especially in cyber security;
- **Distributed ledger technology (DLT), including blockchain**. DLT will have important applications in enhancing security and efficiency for a wide range of areas involving transactions between multiple parties (not just cryptocurrencies);
- **Robotics**. In advanced manufacturing and life sciences sectors the use of robotics will become increasingly prevalent in order to improve productivity. This will include cobots (collaborative robots), which are designed to work safely alongside humans in a shared workspace; and
- **Immersive technology**. Demand for 3D animation is increasing rapidly, and Virtual Reality and Augmented Reality technologies will increasingly be used for entertainment and training.

[24] See the Green Software Foundation

Windows of Opportunity for NI

5.10 The above review of literature and of consultees' views highlights that there are many areas which could lead to significant growth opportunities in NI's software economy over the next decade and beyond. To summarise, these include:

- AI;
- Data;
- Cyber security;
- Cloud;
- Digital transformation;
- Wireless;
- Immersive technology;
- Sustainable technology;
- Edge computing;
- Distributed architectures;
- Internet of Things;
- Low code/no code;
- Robotics;
- Quantum computing;
- Ageing society and digital health; and
- Remote working.

5.11 More broadly, the diffusion and exploitation of software and other IT throughout NI's business base will be critical in boosting NI's productivity performance. There is a large body of economic literature evidencing the positive impacts of IT adoption on economic productivity; note that we do not go into depth here on this subject, as this report is focused on the software economy, rather than the wider exploitation of IT in economies.

5.12 This recognised, taking into account the key industry trends discussed in this Section, the technology/specialism strengths and needs identified in Section 3, the research and innovation capabilities highlighted in Section 4, and the key issues for NI's software economy discussed in the next Section, the study concludes that the most pressing 'windows of opportunity' for NI are in three closely-related areas:

- AI;
- Data science and data engineering; and
- Cloud.

5.13 These are seen as being critically important throughout NI's software sector, but are also areas where NI must grow its capacity and capabilities to remain globally competitive. NI has a 'window of opportunity' over the next five years or so to strengthen its capabilities in these rapidly developing areas. If it fails to do so, there is a real risk of falling further behind competing locations, with adverse consequences for the growth of NI's software economy.

5.14 The following 'Opportunity Area Summaries' set out some more specific key developments in these three areas, and highlight implications for NI's software economy in terms of opportunities and risks. *Readers should note the focus on these three closely-related areas is not to downplay the importance of the other growth opportunities highlighted above, and we are not suggesting that only opportunities in the highlighted three areas should be supported; a mixed approach is required.*

Opportunity Area Summary 1: *Artificial Intelligence*

Aspect	Commentary
Key developments	• **Ethics, trust and regulation**. As AI becomes increasingly integrated with daily life, concerns about ethics, trust and regulation have grown. Issues include algorithmic bias, individuals' right to dignity and privacy, fairness, the transparency and accountability for AI-enabled decisions, and the impact of AI on jobs. The UK Government has recently published a White Paper[25] on its proposed 'pro-innovation' approach to AI regulation; and the European Union is currently developing an AI Act which takes a risk-based approach to regulating AI. • **Explainable AI**. Explainable AI (XAI) is gaining increased prominence, addressing the 'black box' nature of complex AI models and seeking to make AI decisions understandable to humans – especially important in safety-critical applications such as healthcare and critical infrastructure. XAI can also help identify and address model biases. Various techniques have been developed to help users understand how AI models reach their conclusions. The need for appropriate transparency and explainability is one of the five key principles in the UK Government's recent White Paper on AI regulation. • **Generative AI**. Rapid improvements in generative AI have been enabled by recent developments in machine learning model architectures, such as Transformers and Generative Adversarial Networks (GANs), and by increased processing power enabling models to be trained on huge datasets. The launch of ChatGPT in November 2022 sparked a surge of interest in how generative AI could be applied in many different industries. • **Increasing use of AI tools for software development**. Software developers are increasingly using AI tools such as GitHub Copilot, CodeQL, DeepCode, and Tabnine which help them complete, debug, review and test code. • **Increased application of AI in Cyber Security**. As cyber threats continue to proliferate and evolve, there is a growing role for AI in cyber security – helping to identify anomalies, detect malware and automatically respond to breaches in real-time. However, bad actors are also now using AI themselves in creating code, scanning attack surfaces, automating attacks, and generating content for more convincing phishing emails, for example. • **Diffusion and embedding of AI into many industries**. AI is increasingly being applied in many sectors, including healthcare (e.g. assisting in medical image analysis, diagnostics and drug discovery), finance (e.g. detecting fraud, automating insurance claims, customer service chatbots, algorithmic trading), manufacturing (e.g. predictive maintenance, demand forecasting, robotics, quality control) and agriculture (e.g. precision agriculture, crop monitoring, livestock monitoring).
Opportunities for NI's software economy	• Opportunities to **incorporate AI into the software sector's products and services** (including in FinTech, Cyber, Digital Transformation, Data Analytics, and Sensing, Control & Automation). • Opportunities for **applying AI to transform productivity across NI's industries.** • Opportunities for creating and funding **new AI start-ups**, including university spin-outs. • Opportunities for **deepening NI's research excellence** in AI, including in AI ethics, trust, explainability and governance. • Opportunities for **better linking NI's AI research excellence** with the NI business base (in the software sector and other sectors).

[25] *AI regulation: a pro-innovation approach*, DSIT, March 2023

Aspect	Commentary
	• Opportunities to increase productivity by using AI tools to **assist in software development**.
Risks for NI's software economy	• **Potential scale disadvantages**: as AI continues to develop, those parts of the UK which are most successful in generating AI-related economic activity will be the areas most attractive for further AI-oriented companies and people to locate. If NI's AI-related activity grows relatively slowly, then it will find it increasingly hard to compete for AI talent, given the increasing agglomeration advantages of other locations (e.g. London, Cambridge, Oxford, Edinburgh). • **Skills gaps**: increasing gap between supply and demand, as AI skills become increasingly important for the software sector and other industries. • **Potential job disruption**: some fear that the increased use of AI tools in software development could replace software developer jobs (though others expect it to improve productivity and code quality while allowing humans to focus on non-routine tasks).

Source: Steer-ED, DMS Research & Consulting, 2023

Opportunity Area Summary 2: *Data Science and Data Engineering*

Aspect	Commentary
Key developments	• **Advances in AI**. As the capabilities of and applications for AI continue to develop at pace, there is increasing demand for data scientists to build ML models and interpret their results, and for data engineers to build and manage the data pipelines, databases and frameworks necessary for training and implementing the models. AI-powered tools are also being used to help data scientists unlock insights from large datasets, and to help data engineers automate data processing workflows. • **The relentless growth of big data**. The amount of data being generated is growing exponentially, and this is creating new challenges and opportunities for data scientists and engineers in handling and analysing massive datasets. This includes unstructured data (such as text, images, audio, video and social media posts), which enterprises are increasingly analysing using natural language processing and computer vision techniques etc. in order to gain insights and improve productivity. • **Growth of open-source tools**. The proliferation of open-source tools and platforms has been critical in supporting the development of data science and data engineering, democratising access to advanced technologies. Data scientists now have access to a rich ecosystem of free tools such as Python libraries (e.g. Pandas, Seaborn, SciPy, Scikit-learn) and machine learning frameworks (e.g. TensorFlow, PyTorch, Keras). Open-source tools such as Apache Hadoop and Apache Spark are widely used for data storage and processing. • **Developments in data storage and management**. Cloud-based platforms are increasingly being used for storage of data for cloud-native applications. Data lakes (centralised repositories that ingest and store large volumes of data in its original form) and data lakehouses (a hybrid architecture that combines the flexibility and scalability of a data lake with the performance and governance of a data warehouse) have gained significant popularity in recent years. • **DataOps and MLOps**. Borrowing concepts from software DevOps, the disciplines of DataOps and MLOps have recently emerged to apply collaboration, automation and agility in the end-to-end lifecycles for data analytics and for machine learning models.

Aspect	Commentary
Opportunities for NI's software economy	• Opportunities to **underpin growth in AI-related activity** throughout NI's economy, through enhanced data science and data engineering capabilities and synergies. • Opportunities for **continued growth in the Data Analytics sub-sector**. • Opportunities to **develop world-class capabilities in the emerging disciplines of DataOps and MLOps**. • Opportunities to **widen the base of people with data science skills** and experience through exposure to the expanding and rich ecosystem of open-source tools.
Risks for NI's software economy	• **Skills gaps**: increasing gap between supply and demand, as data science and data engineering skills become increasingly important for the software sector and other industries. • **Data security and privacy**: data breaches and privacy violations are significant concerns; if data is not properly protected it can lead to breaches of personal information, trade secrets, regulatory penalties and damage to reputation.

Source: Steer-ED, DMS Research & Consulting, 2023

Opportunity Area Summary 3: Cloud

Aspect	Commentary
Key developments	• **Shift to the cloud**. Enterprises are shifting their computing workloads onto the cloud, using SaaS, PaaS and IaaS offerings. New software products and services are typically now being implemented on cloud infrastructure. By 2025, Gartner estimates[26] that over 95% of new digital workloads will be deployed on cloud-native platforms, up from 30% in 2021. • **Multi-cloud and hybrid cloud approaches**. With the proliferation of cloud services and the need to manage risks and avoid vendor lock-in, many enterprises now use multi-cloud and/or hybrid cloud (mix of public cloud, private cloud and on-premises infrastructure) approaches. New tools and frameworks have been developed to help businesses manage multi-cloud and hybrid cloud environments. • **Serverless computing**. New 'serverless' computing services are now available, such as AWS Lambda and Google Cloud Functions, that make it easy for application developers to deploy code in the cloud without needing to think about provisioning and managing servers. Serverless computing scales up or down to meet demand, and only bills for resources actually used. • **Edge computing**. Edge computing reduces the delay associated with sending data to a centralised cloud server for processing. Applications that require real-time or near-real-time processing (such as IoT devices, autonomous vehicles and industrial automation) benefit from edge computing's quicker response times. Edge computing is increasingly being used to deploy machine learning models directly on edge devices. • **Containerisation**. Containers encapsulate applications and their dependencies, ensuring consistent behaviour across different environments, from development through to production. This portability makes it easier to deploy applications consistently across differing infrastructure setups. Various container-related tools, such as Docker and Kubernetes, have emerged to support container adoption.
Opportunities for NI's	• Opportunities to **extend the use of cloud-based services through the NI economy**, including the public sector, for improved security, performance and reduced carbon emissions.

[26] Source: *Gartner Says Cloud Will Be the Centerpiece of New Digital Experiences*, Gartner, November 2021

Aspect	Commentary
software economy	• Opportunities for **the software sector to develop further cloud management products and services**, such as managing cyber security in multi-cloud environments. • Opportunities for **indigenous start-ups and scale-ups to take advantage of serverless computing**, to minimise time to market and investment in infrastructure.
Risks for NI's software economy	• **Skills gaps**: software sector businesses are needing more people (including graduates) with experience in developing software for cloud environments. • **Potential job disruption**: as computing workloads shift onto the cloud, there is a shift in the nature of IT support required; a reduced need for on-premises infrastructure reduces the demand for in-house and external support for on-premises servers.

Source: Steer-ED, DMS Research & Consulting, 2023

5.15 Perhaps more so than in any other industry, the pace of technological and market change in the software sector is genuinely breathtaking. It will, therefore, be vital that public sector policymakers, business intermediaries, and software firms themselves across Northern Ireland remain alert and forward-looking to change: not only to best leverage that which is predictable, but also to respond agilely and quickly to discontinuous change. This way, long-term resilience for the sector is likely to be best assured.

6 Assessment of Software Cluster Characteristics and Key Issues

6.1 In this Section, we assess the characteristics of the software cluster in NI, and the key issues that need to be addressed in order to support continued strong growth. It primarily draws on the findings from the study's consultations (see Annex B for a list of consultees).

Key Messages

- The software sector in NI demonstrates several features of a well-functioning industrial cluster. In particular, it benefits from: a highly skilled workforce; strong personal networks which are reinforced through a healthy meetup scene and various industry conferences; a strong academic base; areas of specialism, particularly in FinTech, Digital Transformation and Cyber; and agglomeration benefits in Belfast
- The recent launch of the Software Alliance is widely seen as being a very positive development – bringing together NI's software-intensive businesses to collaborate on issues of mutual interest, and providing a more coherent 'voice' for the sector
- However, the limited availability of skilled people is holding back the cluster's further development. The strongest message emerging from this study's consultations was that there is an urgent need to tackle the constrained supply of skills into the industry – both in terms of training up local people, and in attracting in talent from elsewhere. If government and the public sector does nothing else for the software sector, it should make concerted efforts, with education providers and industry, to tackle this – difficult – skills supply challenge
- Software-intensive businesses are at the forefront of remote/hybrid working. Managing this effectively, to maximise the benefits while mitigating the potential downsides, has become a critical management competence
- Most consultees suggested that the public sector should avoid trying to 'pick winners' in terms of specific sub-sectors for support. Value is being created across the software sector, including in smaller but emerging areas as well as the more established areas
- However, there is a case for prioritising the development of capabilities in General Purpose Technologies and disciplines that are clearly going to be increasing important in the future and which will be needed and applied throughout the software economy; specifically, the closely linked areas of Artificial Intelligence, Data Science, Data Engineering and Cloud
- There is a need for more focus on supporting indigenous software businesses, in terms of start-up and scale-up: providing a balance to the inward investments that have been so successful in helping to build up NI's software sector, and offering a broader range of job opportunities

Cluster Characteristics

6.2 The sub-sections below summarise NI's position with respect to the following characteristics which are generally thought to be important for a high-performing industry cluster:

- Skilled workforce;
- Proximity and networking;
- Specialisation;
- Access to markets and customers;
- Supportive infrastructure;
- Cluster leadership and collaboration; and
- Positive externalities.

Skilled Workforce

6.3 When asked what the advantages of NI as a location for software-intensive businesses are, the large majority of study consultees pointed towards the **highly skilled workforce** as the single most important factor. The key features reported were as follows:

- There are excellent universities based in NI, providing industry with high quality graduates and postgraduates;
- The FE sector is well engaged with the software sector, and efforts are being made to develop links between businesses and schools;
- Initiatives such as the well-regarded Assured Skills programme are helping, pre-employment, to provide individuals with the skills needed to compete for new employment opportunities in the software sector;
- There is a strong density of core software engineering skills (e.g. Java, JavaScript, C#) within NI;
- Alongside the technical skills, several consultees identified an advantage for NI in terms of *culture*: NI has a strong engineering heritage, and this has helped to create a good work ethic and a continuous improvement mindset;
- Although there were some criticisms of the impact of FDI (see below, under Key Issues), it was also acknowledged that FDI has helped build up the software sector's scale, knowledge and expertise that would not have otherwise existed in NI: acting as a skills development engine for the software economy.

6.4 Linked with the skilled workforce advantage is the fact that NI is **lower-cost** compared to some alternative locations for software business operations. In particular, notwithstanding recent salary inflation in the sector, it is still significantly cheaper to hire software developers in NI than in the US or Dublin.

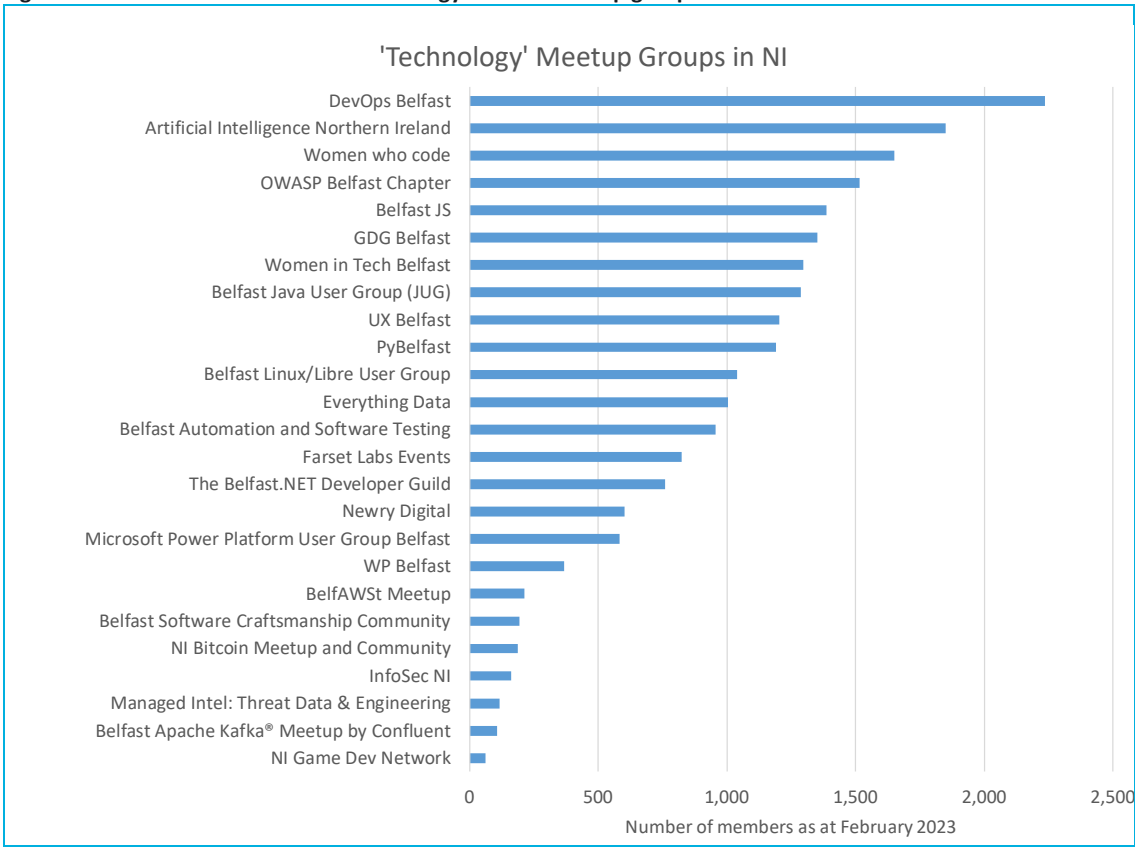
6.5 However, most consultees also identified the **limited availability of skilled people** as the most important issue which was holding back the further growth of NI's software economy. It was felt that more could, and should, be done to boost the supply of people interested in and capable of pursuing a career in software. We discuss this further under 'Key Issues' below.

Proximity and Networking

6.6 NI is a **relatively small and well-connected place,** with the result that 'everyone knows everyone' within the software sector. It is generally straightforward to establish new contacts, with there being very few 'degrees of separation' between people in NI's software economy. Some consultees commented very positively on the willingness of individuals in the software ecosystem to offer help and advice when asked.

6.7 There are various opportunities for peer-to-peer networking within NI's software economy. For example, an analysis of Northern Ireland-based Meetup groups in the 'Technology' category (Figure 6-1) confirms that **there is a healthy meetup scene in NI, with 12 groups each having more than 1,000 members**. All but one of these Meetup groups (Newry Digital) is listed as being Belfast-based, although it should be noted that some events are held online.

Figure 6-1: Number of members in technology-related Meetup groups



Source: Meetup.com, February 2023

6.8 Various software-related tools, disciplines and methodologies/approaches are represented in these Meetup groups, such as DevOps, Artificial Intelligence, web application security, JavaScript, Java and User Experience (UX). Women Who Code (1,650 members) and Women in Tech Belfast (1,295 members) seem also to be well-established – helping to address the gender imbalance in this sector.

6.9 Regular **conferences** include BelTech, NI DevCon, AI Con and Big Data Belfast. NI has also recently hosted the national CYBERUK 2023 conference.

Knowledge and Innovation

6.10 As explored in Section 4, NI has various strengths in terms of software-related research and innovation. QUB and UU provide a **strong and complementary academic base**; for example, UU came 9th out of 90 in REF 2021 for Research Power in Computer Science & Informatics. QUB is particularly noted for a world-class strength in cyber security, and both universities are strong in Artificial Intelligence.

6.11 A 2019 review of AI research in Northern Ireland[27] noted that, for AI papers published in 2014-2017: *'As a combined entity, UU/QUB ranks 6th in the UK in terms of AI outputs, 9th in terms of publications in Top Journal percentiles; 11th in terms of outputs in Top Citation percentiles; and 12th in terms of Citation Count. There is no doubt, therefore, that UU and QUB together constitute a major force in the AI research field in the UK.'*

6.12 Both universities have created **successful spin-out companies**, most notably Kainos, which was spun-out from QUB in 1986 and now employs over 3,000 people globally.

6.13 However, the study's consultations did reveal some concern that there are **not enough indigenous start-ups and scale-ups coming through**, and the analysis in Section 3 of this report confirms that NI is 'underweight' in terms of smaller software businesses. This is discussed further under 'Key Issues' below.

Specialisation

6.14 The study's desk research, confirmed through the broad programme of consultation with businesses, HE, FE and wider business support organisations, have identified areas of particularly strong capabilities in NI:

- Amongst the company base, the strongest areas of specialism in NI are **FinTech**, **Digital Transformation**, **Cyber**, **Data Analytics** and **Sensing, Control & Automation**.
- From the analysis of computer science-related journal articles published over the last ten years by authors from Queen's University Belfast and Ulster University, **'Artificial Intelligence'**, **'Computer Security'** and **'Telecommunications'** stand out as the areas with the highest impact; and these are areas in which the two universities are generally acknowledged to be particularly strong.

6.15 There are also smaller but emerging specialisations such as **EdTech** and **Retail Tech**.

6.16 Overall, the level of specialisation within NI's software sector seems to be striking an **appropriate balance** at present: sufficiently specialised to create benefits of scale in a few particularly strong areas, diverse enough to limit the economic risks of downturns in specific sub-sectors, and agile and entrepreneurial enough to exploit new opportunities as these start to break.

Access to Markets and Customers

6.17 The fact that NI uses the **English language** is helpful from the perspective of US-based inward investors, in terms of easing communication across international teams. The **time zone** was also cited as a useful factor: allowing overlapping working days with teams based in East Coast US, and also with teams based in India.

6.18 There is a notable **lack of local large customers**, however. While NI's public sector could potentially be a large anchor customer for local NI software businesses, some consultees were of the view that the public sector seemed to have a preference for larger non-NI software suppliers.

6.19 **Northern Ireland's sharing a land border with an EU Member State** is an unmatched competitive advantage geographically in a UK context. Access to the market is physically easy, culturally aligned, and cross-border working is a natural part of the way that the island of

[27] Source: *Artificial Intelligence Research in Northern Ireland and the Potential for a Regional Centre of Excellence*. Alan Turing Institute, 2019

Ireland economy works. These are all positives to be exploited and, importantly, demonstrated. Set against this, however, the pull of the Dublin labour market and the opportunities created by the major commitment of the Irish government to developing its own IT sector are potential competitive threats to Northern Ireland's software sector.

Supportive Infrastructure

6.20 The cluster has a number of **organisations which help to bring the community together** and support growth, including Digital DNA, Digital Catapult, Catalyst and Ormeau Baths. The availability and long-term stability of attractive FDI assistance from Invest NI was mentioned by some consultees as an advantage for NI in securing inward investment.

6.21 An underpinning advantage is the **quality of life** on offer to people living and working in NI: including relatively affordable housing, a high-quality education system, relatively short commutes, and ready access to beautiful countryside.

6.22 **Digital infrastructure** is generally good: in particular, NI has by far the highest full fibre coverage of any UK nation[28] (89% in NI, vs 48% for the UK in January 2023).

6.23 However, some consultees commented on some **transport-related weaknesses** that they felt were a hindrance. In particular, the current lack of direct scheduled air routes to the US was seen as a problem (although we note that a new low cost transatlantic carrier, Fly Atlantic, is planning to launch services in summer 2025). The study also heard some criticism of the road infrastructure outside Belfast, and the quality/frequency of public transport options.

6.24 Other consultees suggested that there is a **need for further 'place-making'** in terms of the housing, public domain and leisure offer, to help NI (and Belfast in particular) compete with Dublin, London, Cambridge, Edinburgh, Cardiff and other cities as an attractive place to live and work.

Cluster Leadership and Collaboration

6.25 The recent launch of the **Software Alliance** is widely seen as being a very positive development – bringing together NI's software-intensive businesses to collaborate on issues of mutual interest, and providing a more coherent 'voice' for the sector: something that has been lacking in recent years.

6.26 It is, however, early days for the Software Alliance as an organisation, and it will take time to develop the scope and scale of its activities. Although NI also has **NI Cyber and Fintech NI** which are helping to bring together players in the more specific fields of cyber security and fintech, other parts of the UK have local tech associations/cluster organisations which are considerably more established (e.g. Scotland IS, Cambridge Network and Manchester Digital).

6.27 In terms of collaboration across the cluster, there are **several examples of local businesses collaborating closely with the universities** in terms of both research and skills development (including input to course content and placements for students). There are **fewer examples of business-to-business collaboration on innovation**, though the Cyber-AI Hub to be hosted at QUB is one (bringing together eight R&D intensive cyber security companies with an interest in AI-related innovation), with the Digital Catapult being a second.

[28] Source: Connected Nations Update: Spring 2023, Ofcom

Positive Externalities

6.28 With the bulk of NI's software-intensive business located in or around Belfast, there are **agglomeration benefits in Belfast** that help to create momentum and profile for the sector. As the number of software-related businesses increases and as software-related employment opportunities increase, NI becomes more attractive both for businesses (accessing a deeper labour market) and individuals (with a wider range of job opportunities available): a virtuous circle.

6.29 Acting against this, however, the study's consultations highlighted the difficulties in attracting senior software talent and senior commercial executives. It would appear that **NI is yet to reach a tipping point** beyond which there are clearly so many senior level opportunities that it is low-risk for senior talent to re-locate to NI.

Key Issues

6.30 The key issues, as identified by the study's desk research and consultations, to be tackled in strengthening NI's software cluster and further developing the software economy are set out below.

Skills Availability

6.31 The strongest message emerging from this study's consultations was that there is an **urgent need to tackle the constrained supply of skills** into the industry – both in terms of training up local people, and in attracting in talent from elsewhere (including from countries requiring visa clearance). Northern Ireland has a world-class talent base, and its software engineers are internationally recognised as being highly skilled and having a great work ethic. However, there is just not enough of them to meet the demand, and this is leading to significant recruitment problems for both indigenous and inward investor companies, and is constraining the growth of the sector in NI. The latest NI Skills Barometer[29] highlighted that the occupation with the highest net requirement in the period 2020 to 2030 will be information technology and telecommunications professionals.

6.32 Business consultees reported that they had seen very **strong salary inflation** over the last two years, and this is making it increasingly difficult and expensive to hire software talent in NI. In common with other parts of the UK and other countries, demand is outstripping supply, and this is pushing up salaries and increasing pressures to offer generous benefits packages. While this is clearly beneficial for individual workers in the industry, it is also constraining the extent to which the sector as a whole can expand, as NI's cost advantage versus other locations reduces and as smaller indigenous businesses struggle to recruit and grow.

6.33 The situation has been **exacerbated by the shift in working patterns** accelerated by COVID-19 lockdowns. Having pivoted to an entirely remote model during lockdowns, software companies in relatively expensive locations such as London and the US have become more comfortable in hiring individual staff members working remotely from home in locations such as NI. The higher salaries on offer from these businesses help to push up the overall salary levels in the NI jobs market.

6.34 A number of consultees noted that (mostly US-based) **FDI companies in NI could generally afford to offer higher salaries** and more generous benefits packages than indigenous

[29] Source: Skills Barometer Update 2021, Ulster University, March 2022

businesses, given the differentials in salary levels between the US and NI. **Small local businesses are finding it very difficult to compete for talent** – unable to match the entry-level graduate salaries offered by larger firms and seeing some of their experienced staff leaving for salary increases of 20% or more.

6.35 Consultees reported that it is **difficult to attract experienced people to locate and indeed re-locate to NI from outside the region**, especially at C-suite level. As a result we are seeing more hiring of remote workers – people based in GB and the Republic of Ireland (RoI), but working for NI businesses. While this supports the continued growth of these companies, the economic benefits to NI are limited as those workers' wages are not being spent in the local NI economy, and their recruitment is not helping to deepen the local NI labour study's market.

6.36 It is also perceived that **RoI-based businesses find it much easier to import talent** from the EU and from non-EU countries than is the case for NI-based businesses. Although Skilled Worker and Global Talent visas are available, the bureaucracy and cost of these routes are significant deterrents, especially to smaller businesses. A consultee from a large business with operations in both countries noted that it was considerably easier to bring external (EU and non-EU) talent into RoI than into NI.

6.37 Many consultees were critical that the **education system as a whole in NI is failing to equip sufficient numbers of young people with skills in coding and computational thinking**[30] which are increasingly essential to high value jobs in a modern economy, whether in the software sector or other industries, with the main feedback from consultees suggesting:

- Although 'Using ICT' is one of three cross-curriculum skills in the NI curriculum, computer science is not a mandatory part of the curriculum in NI (whereas it is in England, to KS4);
- Not enough schools are offering computing courses and actively encouraging take-up of this subject area. Some consultees suggested that teachers may be steering students towards 'easier' subjects in order to keep their schools' overall attainment rates up;
- The extent to which coding is introduced to primary school children is very variable in NI. A pupil enthused by coding at their primary school may find themselves bored by ICT-related lessons when they transition to KS3, with the teachers teaching to the lowest common denominator of ability;
- Schools, FE colleges and universities find it difficult to attract and retain computing teachers as the salaries available in industry are considerably higher;
- Too few computing teachers are given sufficient opportunities for Continual Professional Development in this fast-moving area;
- Not enough young people see computing as an attractive option to study at school, FE and/or university. In particular, female participation rates are chronically low: just 12% of those taking Computing at A level and 24% of those taking Computing at university;
- Not enough parents and teachers are aware of the variety and quality of jobs available in the software economy;
- There are various initiatives for businesses to engage with schools to raise the profile of NI's software sector, but these are not joined-up and often lack input from education specialists; and
- Not enough places are available at NI's universities for computing courses, with the MaSN system constraining overall student numbers at QUB and UU.

[30] See Section 2 for secondary data on the skills supply issue

6.38 There is also a perceived **lack of joined-upness** across government departments in addressing this skills issue. **If government and the public sector does nothing else for the software sector, it should make concerted efforts, with education providers and industry, to tackle this difficult skills-supply challenge**.

Remote Working

6.39 The pandemic lockdowns have led to a **sea-change in working patterns**, with a shift to remote and hybrid working which is persisting in many industries. Software-intensive businesses are at the forefront of this change, as their employees and managers tend to be comfortable with using technology to enable efficient remote/hybrid working and the type of work lends itself to being done from home as effectively as in the office.

6.40 Consultees noted that this has generally been **popular with employees**, as it provides more flexibility, cuts down on commuting, and helps improve work-life balance. However, a number of **potential downsides** were also noted, particularly in the risk of some people feeling isolated, in inducting new recruits into company cultures and systems/processes, in the personal development of younger staff and the virtuous inter-generational sharing of knowledge, and in terms of the innovations resulting from 'water-cooler moments'. Managing remote/hybrid working effectively, such that the benefits are maximised while the downsides are minimised, has become a **critical management competence**.

6.41 Furthermore, as noted above, there is anecdotal evidence of an increase in the numbers of people choosing to work remotely in NI for non-NI businesses. Although there is no data on the numbers involved, the study suggests that **these remote workers should be considered an integral part of NI's overall software economy**, not least because they are typically experienced people that are in high demand by local NI software-intensive businesses. There are particular **challenges in ensuring that these people remain well-connected** with the local software ecosystem in NI: there is no single organisation with an obvious remit to take the lead in reaching out to these remote workers which are not attached to a local NI business.

Need to Bulk-Up in Key Technologies

6.42 In the study's stakeholder consultations, a majority of interviewees suggested that the **public sector should avoid trying to 'pick winners'** in terms of specific *sub-sectors* for support. Value is being created across the software sector – including in smaller but emerging areas (such as EdTech and Retail Tech) as well as the larger, more established areas (such as FinTech, Digital Transformation and Cyber).

6.43 However, the study's consultations and wider desk research of best practice and experience point to there being a strong case for prioritising the **development of capabilities in General Purpose Technologies[31] and disciplines** that are going clearly to be increasing important in the future and which will be needed and applied throughout the software economy; specifically, the closely linked areas of **Artificial Intelligence**, **Data Science**, **Data Engineering** and **Cloud**:

- **Artificial Intelligence** is a broad field which involves developing algorithms and models that enable machines to learn, reason, perceive and make decisions. AI encompasses various subfields, including machine learning, natural language processing and computer

[31] General Purpose Technologies (GPTs) are technological innovations that have substantial impacts across many industries. They have the potential to drive economic growth through enabling new business models and increasing productivity in existing sectors.

vision. The public launch of the generative AI tool ChatGPT in late 2022 helped raise public awareness of the potential for AI in many different fields. AI was widely seen by the study's consultees as a critical technology in shaping the future of the software sector, as well as being widely applicable across all industry sectors. Many of NI's software businesses are seeking to integrate AI capabilities into their product and service offerings;

- **Data Science** involves extracting insights and knowledge from structured and unstructured data. It combines statistical and mathematical techniques, programming skills and domain knowledge to uncover patterns, make predictions, and solve complex problems. Data scientists use tools and algorithms to collect, clean, analyse and interpret large datasets. They apply machine learning and statistical models to extract actionable insights, build predictive models and make data-driven decisions. The study's consultees noted that data science posts are particularly difficult to fill in NI; one stakeholder workshop attendee reported that it had recently been cheaper to employ a data scientist working remotely in London than to hire locally;
- **Data Engineering** focuses on the design, development, and maintenance of the systems and infrastructure required to handle large-scale data processing. Data engineers build and manage the data pipelines, databases and frameworks necessary for storing, processing and transforming data. They work on data integration, data warehousing, data governance, and ensure data quality, reliability and scalability. Again, consultees noted that experienced data engineers are very hard to recruit in NI; and
- **Cloud** computing involves delivering computing resources and services over the internet, providing on-demand access to a shared pool of configurable computing resources, such as servers, storage, databases and software applications. It has become an integral part of many businesses and industries, enabling organisations to innovate, scale and leverage advanced technologies without the need for extensive infrastructure investments and management. Leading cloud service providers include AWS (Amazon Web Services), GCP (Google Cloud Platform) and Microsoft Azure. Software products and services are increasingly being delivered using cloud infrastructure, and many consultees noted that NI is currently underweight in terms of people with expertise in how best to develop and deploy software to run in the cloud. There was some criticism that computing students are not being sufficiently exposed to cloud infrastructure at the universities.

6.44 Spanning all four of these areas, the new discipline of **MLOps** (Machine Learning Operations) has emerged over recent years: the practices and technologies used to streamline and automate the deployment, monitoring, management, and maintenance of machine learning models in production environments. Given NI's longstanding engineering heritage and its more recent core software engineering strengths, there would appear to be strong potential for NI to develop as a centre of excellence in MLOps.

6.45 While NI already has several **examples of genuine strength** in the technologies and disciplines highlighted above, both in the company base and academia, the study's desk research and consultations conclude that **NI as a whole is currently underweight relative to the UK in these areas**: both in terms of the existing skills base and the jobs that are currently being advertised.

The Need for a Stronger Indigenous Start-up/Scale-up Pipeline

6.46 The desk research summarised in Section 3 highlights that NI is considerably **underweight in terms of micro-businesses in software-related areas**. The study's consultations suggest that this could be for one or more of the following reasons:

- Small indigenous businesses struggle to recruit and retain talent, given the strong demand from larger businesses, including FDI companies;
- With plenty of demand for software talent from large companies offering generous benefits packages, there is less appetite for individuals with software skills to take the risk of setting up their own business; and/or
- Some consultees considered that there had been less support for software start-ups recently. There was some comment around Invest NI's de-funding of Ignite NI's accelerator and the Propel pre-accelerator, as these were perceived to have been successful programmes.

6.47 A few consultees also suggested that **small businesses find it harder than large companies to engage with the universities** on research collaborations, and others noted that it is **harder for the FE sector to engage with large numbers of small businesses** on skills development initiatives such as Assured Skills Academies than it is with a small number of large businesses.

6.48 **Kainos** (founded 1986), **FD Technologies** (founded 1996) and **FinTrU** (founded 2013) are terrific examples of indigenous software businesses that have successfully scaled up to become large global operations. However, some consultees noted that these were exceptions for NI's software sector: **no other indigenous software firms founded in NI have yet managed to achieve similar levels of scaling-up success**.

6.49 Several consultees considered that there is a **need for more focus on supporting indigenous software businesses**, in terms of start-up and scale-up: providing a balance to the inward investments that have been so successful in helping to build up NI's software sector, and offering a broader range of job opportunities.

Other Issues

6.50 Other issues highlighted by study consultees included the following:

- The current **lack of a NI Executive** was widely cited as being unhelpful for the sector, as it constrains effective policy development ('nothing gets decided'), and the uncertainty that it creates is deterring investment to some extent, as well as deterring potential re-locators;
- There is a notable **lack of local large customers in Northern Ireland**. While NI's public sector could potentially be a large anchor customer for local NI software businesses, some consultees were of the view that the public sector seemed to have a preference for larger non-NI software suppliers;
- Some consultees commented on some **transport-related weaknesses** that they felt were a hindrance. In particular, the current lack of direct scheduled air routes to the US was seen as a problem. We also heard some criticism of the road infrastructure outside Belfast, and the quality/frequency of public transport options;
- Other consultees suggested that there is a **need for further 'place-making'** in terms of the housing, public domain and leisure offer, to help NI (and Belfast in particular) compete with Dublin, London, Cambridge, Edinburgh, Cardiff and other cities as an attractive place to live and work; and
- There were **mixed views on access to finance**: some thought that the VC 'mainstream' was now taking NI seriously as a location for investment, building on the work of some earlier pioneers from Dublin, while others thought that access to VC 'within and for' NI

was still poor. Data from Tech Nation[32] provides some grounds for cautious optimism on this: it estimates that there was a total of $150 million VC investment into tech companies in Northern Ireland in 2022, up from $57.5 million in 2021 and $34.7 million in 2019. It may be that there is a particular issue around later stage equity funding, however: research for the British Business Bank[33] found that gaps in later stage equity for SMEs were mentioned almost twice as much in NI as in the UK overall (38% versus 20%, respectively).

[32] Source: Tech Nation Report 2023

[33] Source: Access to Finance Spotlight: UK findings, British Business Bank, Spring 2021

7 Assessment versus 10X Priorities

7.1 In this Section, we assess briefly the extent to which Northern Ireland's software economy is helping to address the 10X priorities of being:

- Innovative;
- Sustainable; and
- Inclusive.

Key Messages

- The software sector invests heavily in R&D and is an innovation-intensive industry. There are, however, some factors which constrain its innovative potential including being relatively underweight in micro-businesses, difficulties in recruiting for PhDs and post-docs in the areas of AI and data science, under-representation of women in the workforce, and the limited scope of roles offered within NI in some FDI operations
- Although it is not a major area of specialism within NI's software sector, there are various NI businesses developing software to help reduce waste and carbon emissions. The ongoing shift to the cloud is important in improving the sustainability of the industry
- Of the three 10X priorities, NI's software economy is arguably weakest when it comes to the 'Inclusive' priority. In particular the participation of females is chronically low. If 10X is to achieve its objective to 'create opportunities for economic growth which are distributed across society to benefit everyone' then the current inequities in access to computing education will need to be addressed, and more concerted and effective efforts will need to be made to get more girls interested in coding and to encourage women into software occupations.

Innovative

7.2 Software was chosen as a priority cluster for 10X partly because it is seen to be **an innovation-intensive sector**. The desk research and consultations for this study have confirmed this. For example, analysis of R&D tax credit data found that the Information & Communications sector accounted for 26% of R&D expenditure in NI – its highest share in any UK nation or region. In the latest Innovation Survey (for 2018-2020), 63% of UK firms in 'Computing and related activities/ICT' were innovation-active: one of the highest ratios for any sector and considerably higher that the overall UK average of 44.9% and the NI average of 38.4%.

7.3 Section 4 of this report provides several examples of the considerable innovative activity underway in both the business base and academia.

7.4 In terms of potential **risks** to innovative activity, the study's research highlighted the following:

- NI's software sector is relatively **underweight in micro-businesses**, which play an important role in introducing disruptive innovations. The study heard evidence that small

indigenous software businesses are struggling to recruit, with the intense competition for talent from larger companies, including FDI firms;
- The universities report **difficulties in recruiting for PhDs and post-docs in the areas of AI and data science**, given the salaries that are available in industry (compared with the current research studentship maintenance stipend of £17,668 p.a.). This is a potential concern for future development of the universities' research and innovation capacity in this area;
- The **under-representation of females in the software economy** workforce (see below, under 'Inclusive') means that the sector is largely missing out on the innovative potential and diversity of perspective offered by women; and
- In some FDI firms, there is a rather **limited scope of leadership roles** being undertaken in NI, with activity primarily focused on software development tasks while commercial and strategic decisions are made elsewhere. This constrains the extent to which NI is growing commercial and senior decision-making talent in the software business base.

Sustainable

7.5 Although it is not a major area of specialism within NI's software sector, sustainability is an important concern for many software firms, and there are various NI businesses developing software to help reduce waste and carbon emissions. For example:

- Sensata Technologies is planning a new £16.5 million R&D facility at Global Point Business Park for its engineering and software development teams. Sensata's sensors are used for a very wide variety of applications, including improving fuel efficiency and emissions of vehicles.
- The Electric Storage Company has developed software to build up a profile of customer electricity use and automatically make a choice of whether to use any local solar energy immediately, store it for future use or sell excess electricity back to the grid.
- See.sense provides products that generate data to help city authorities improve their cycling infrastructure.
- SustainIQ has developed a software platform to help companies manage their ESG and sustainability reporting.
- Kainos has a Director of Green Software, focused on introducing green software practices to the build and operation of software services to reduce their carbon and environmental footprint.

7.6 The **shift to cloud-based solutions** is seen as being important in helping to reduce the greenhouse gas emissions associated with IT, as shared cloud infrastructure is typically more energy efficient than on-premises servers. For example, a study by Microsoft and WSP estimates that the Microsoft cloud is 22% to 93% more energy efficient than traditional enterprise data centres[34].

7.7 However, one trend working in the other direction is that **large machine learning models require electricity-hungry processing power** for their training. For example, it has been estimated[35] that training OpenAI's GPT-3 model required about 1.3 gigawatt-hours of electricity. As AI becomes increasingly integrated into the software sector's offerings, the electricity consumed for training and applying models is set to increase.

[34] Source: *The Carbon Benefits of Cloud Computing: a Study of the Microsoft Cloud*, Microsoft and WSP, 2020

[35] Source: *Carbon Emissions and Large Neural Network Training*, Patterson et al, April 2021

Inclusive

7.8 Of the three 10X priorities, NI's software economy is arguably weakest when it comes to the 'Inclusive' priority. In particular the **participation of females is chronically low.** Females accounted for:

- 23.5% of GCSEs sat in Digital Technology Programming in summer 2022
- 12.3% of Computing A-levels sat in summer 2022
- 24% of Computing students at NI's HEIs in 2021/22
- 27% of employees in NI's software industries in 2022
- 17% of NI residents in software occupations in 2022.

7.9 While this is an issue affecting the UK as a whole (and many other countries), the **situation in NI seems to be particularly pronounced**. In England, females accounted for 15.2% of students sitting Computing at A-level (12.3% in NI), and in the UK 20% of people in software occupations are female (17% in NI). In terms of Higher Education, NI is broadly in line with the national average for female participation in Computing (23% in the UK versus 24% in NI).

7.10 As previously noted, the sector employs **relatively few people with a long term health problem or disability**. According to the 2021 census, only 7.4% of NI residents working in SIC 62 (Computer programming, consultancy and related activities) had a long term health problem or disability that limited their day-to-day activities, versus the Northern Ireland average of 11.0%. However, efforts are being made to make the sector more inclusive. For example, Specialisterne NI has supported neurodiverse people access job opportunities in NI's software sector – including partnering with Microsoft to support neurodiverse applicants to Microsoft Assured Skills academies.

7.11 In terms of **regional inclusion**, Belfast has 40% of NI's total business sites in software-related SICs (compared with its 18% population share), and is dominant in terms of the sites which have 10 or more employees. However, **the increased prevalence of remote and hybrid working is helping to spread the software sector's economic activity more widely across NI**.

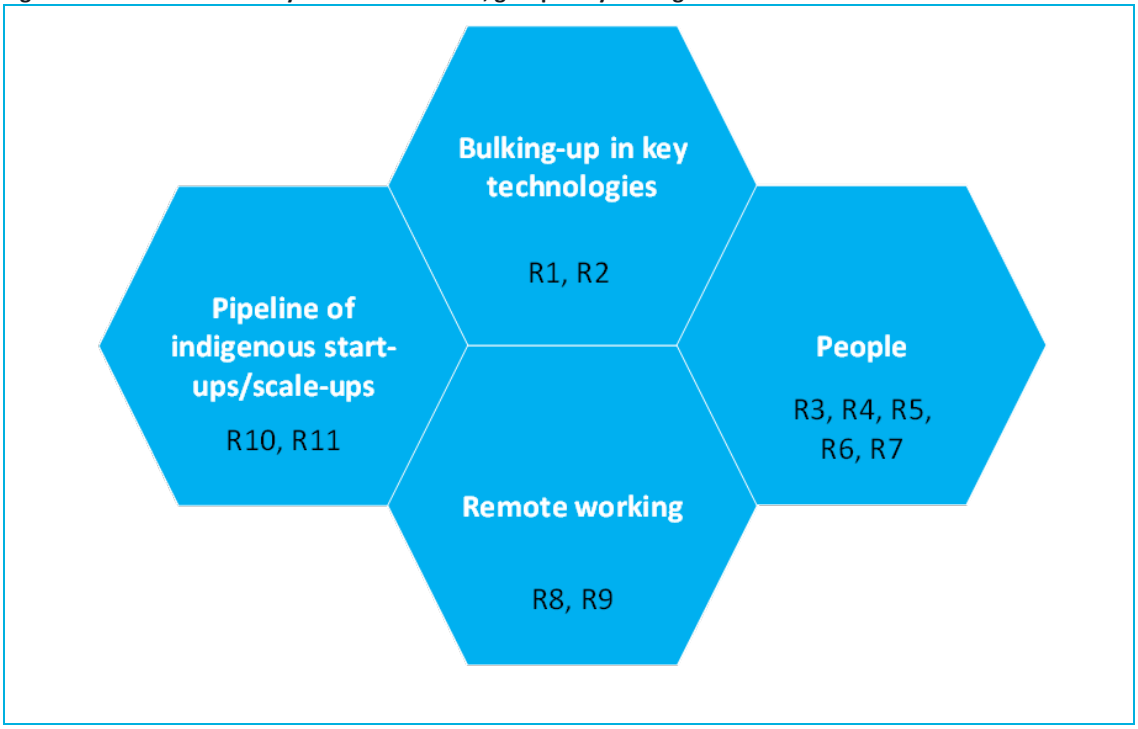
7.12 Some consultees also pointed out the **unfairness of computing only being offered at a minority of schools** at GCSE and A-level. If 10X is to achieve its objective to *'create opportunities for economic growth which are distributed across society to benefit everyone'* then the current inequities in access to computing education will need to be addressed, and more concerted and effective efforts will need to be made to get more girls interested in coding and to encourage women into software occupations.

8 Recommendations

8.1 Based on the findings and conclusions of this study as set out in Sections 2 to 8, including the 'windows of opportunity', the study offers 11 recommendations to help enable NI's software economy realise its potential. The recommendations are grouped under four strategic themes, as follows:

- The need to grow NI's capacity and capability in the **key technologies** of AI, data science, data engineering, and cloud
- The need to increase the number of **people** available to work in NI's software economy
- The need to optimise the economic impact for NI of **remote working**
- The need to develop a stronger **pipeline of indigenous start-ups and scale-ups**.

Figure 8-1: Overview of study recommendations, grouped by strategic theme



Source: Steer-ED, 2023 and DMS Research & Consulting

Growing Capacity and Capability in Key Technologies

Recommendation 1: DfE should seek to strengthen NI's position in the widely-applicable technology competences of AI, data science, data engineering and cloud, rather than focusing support toward specific narrowly-defined software sub-sectors.

8.3 This study's desk research and consultations found that it will be increasingly important for NI to have really strong technology competences in AI, data science, data engineering and

cloud[36], given industry trends. These are technologies which will be increasingly vital in addressing new market opportunities and productivity growth, both within the software sector itself and across NI's industrial base, including Life Sciences, Fintech, Advanced Manufacturing and Agritech.

8.4 This is not intended to be a comprehensive list of important technologies and is certainly not to say that other technologies/disciplines (e.g. in cyber security, green software, quantum computing, robotics) will be unimportant or should not be supported. Equally, it is not to say that NI's particularly strong sub-sectors (e.g. FinTech and Digital Transformation) should not continue to be supported. Rather, these technologies (AI, data science, data engineering and cloud) are highlighted as areas where there is the most pressing need for strengthening NI's position in order to remain globally competitive.

8.5 While NI already has several examples of genuine strength in these technologies, both in the company base and academia, the findings of this study suggest that NI needs to grow its overall capacity and capabilities in these areas in order to remain competitive and further grow the software sector. For example, there may be opportunities for NI to become a centre of excellence in MLOps (Machine Learning Operations): the practices and technologies used to streamline and automate the deployment, monitoring, management, and maintenance of machine learning models in production environments.

8.6 Guided by the views of its consultees, the study proposes that it is more appropriate for DfE to focus on strengthening NI's position in these specific widely-applicable *technologies* rather than picking particular software *sub-sectors* for *preferential* support. Value is being created across the software sector – including in smaller but emerging areas (such as EdTech and Retail Tech) as well as the larger, more established areas (such as FinTech, Digital Transformation and Cyber).

8.7 The role of FDI in helping to boost NI's capabilities in AI, data science, data engineering and cloud will need to be carefully considered. Well-targeted FDI could facilitate talent development, knowledge sharing, access to global expertise, and help develop critical mass for NI in these areas. However, further FDI also increases competition for local talent, and the risks around this will need to be managed.

Recommendation 2: DfE should boost the funding available for PhDs and post-docs in software-intensive disciplines, especially in AI, data science and data engineering.

8.9 With the recent strong salary inflation in the software sector, NI's cost advantages versus other locations is being reduced somewhat. Over the next decade NI's competitive advantages will increasingly rely on other differentiators such as cutting edge tech capabilities emerging from the universities.

8.10 However, the universities report difficulties in recruiting PhDs and post-docs in areas such as AI and data science/data engineering, given the competition for these skills from industry. Bearing in mind the role of PhDs and post-docs in supporting academic research, this could

[36] By 'cloud' we are referring here to the technology competences required to *use* cloud infrastructure optimally (e.g. how to develop and implement software that will run efficiently in the cloud), rather suggesting that DfE needs to bring more cloud infrastructure into NI.

constrain the extent to which QUB and UU can further develop their research strengths in these important areas.

8.11 As AI, data science and data engineering are seen as being particularly critical to the growth of the software sector and to the wider industrial base, DfE should seek to ensure sufficient funding is made available for PhDs and post-docs in these areas. As well as increasing the availability of postgraduate recruits into NI businesses, this will help create new knowledge and innovations relevant to the software sector, provide new opportunities for collaboration between industry and academia, and should also boost the flow of new software-intensive start-up ventures emerging from the universities.

8.12 More widely, the universities operate in a global context: pursuing world-class excellence in their research, with societal impacts that extend well beyond NI. Their capabilities in software-intensive disciplines such as AI, data science and data engineering will increasingly underpin research excellence across many different subject areas.

People

Recommendation 3: DfE and DE should jointly research global best practice in computing education from primary through to tertiary levels, assess the applicability of initiatives/policies to the NI context, and implement pilots of the most promising approaches.

8.14 Tackling the computing education of young people is inherently challenging, given the fast pace of change in computing, the difficulties in re-skilling, recruiting and retaining teachers in this area, and misplaced perceptions of the subject amongst student, their parents and teachers.

8.15 This challenge is an issue that is common internationally, and there have been a variety of approaches adopted around the world. Countries such as Israel, Finland, Estonia, South Korea and Singapore are sometimes held out as examples of good practice in computing education at school. In the tertiary sector, top US universities such as MIT, Stanford, Carnegie Mellon and UC Berkeley are widely recognised for their strong computer science departments.

8.16 Seeking a holistic view across the spectrum of education, DfE and DE should undertake research to identify examples where countries/states have achieved world-leading outcomes (e.g. in terms of the proportion of young people able to code) and understand what approaches have contributed to this. This research should include QUB and UU, given their ongoing interests in international benchmarking and best practice in education. At the tertiary level, the research could also consider what constitutes global best practice in terms of entrepreneurship/management education of technical students.

8.17 Where such good practice is applicable to the NI context, pilots of the most promising approaches should be implemented and evaluated for wider roll-out. Along with recommendations 4, 5 and 7, this recommendation should help tackle the current low levels of female participation in computing education and NI's software economy.

Recommendation 4: DE should set out an ambition for all NI's primary and post-primary schools to equip their students with computational thinking and coding skills, and develop a strategy and timescale for achieving this, in liaison with CCEA, ETI, schools, DfE, the universities and industry.

8.19 Many of the study's consultees considered that the root of NI's skill supply issue stems back to school: not enough NI children are being enthused by coding (especially girls), too few schools are offering education in computing (as opposed to education in the use of ICT), and far too few pupils are choosing to study Computing at GCSE and A-level.

8.20 With the advent of more accessible and powerful programming languages such as Python, we suggest that coding (and the computational thinking skills behind it) is becoming an essential life-skill for many high value jobs and careers. Programming is not now restricted to specialist software developers. It is a skill needed by data scientists and analysts, cyber professionals, robotics engineers and financial analysts, for example.

8.21 In England, computer science (including coding) has been a mandatory part of the curriculum through to KS4 since 2014. While there were certainly issues around its introduction, it is striking that the proportion of pupils sitting Computing A-level in England is now nearly *double* that in NI, whereas the proportions were similar in 2017.

8.22 To help deliver 10X and maintain its international competitiveness, NI really needs to tackle the dearth of computational thinking and coding education for young people. Radical solutions are likely to be needed in training, recruiting, and retaining computing teachers. Options might include, for example: providing generous bursaries for Initial Teacher Training in Computing; early career additional payments; collaboration between schools and FE; and remote/hybrid learning approaches that increase the 'reach' of the best teachers. Options such as including Computing as a mandatory Area of Learning in the Curriculum, and offering Computing or coding modules in Maths courses should also be carefully considered.

> **Recommendation 5**: With the universities, the FE sector and industry partners, DfE should seek to substantially grow the numbers of people obtaining Computing-related skills and qualifications, through a variety of pathways, at a pace which matches the growth of NI's software economy.

8.24 There are various pathways into a career in software: the traditional undergraduate Computer Science route at QUB, UU and the Open University is now supplemented by HE in FE, post-graduate full-time or part-time conversion courses such as those offered through Skill Up, Higher Level Apprenticeships(HLAs), Assured Skills Academies and Level 4/5 FE qualifications.

8.25 The strongest message from the study's consultations was that the growth of the software sector is currently being constrained by a shortage of people with software skills. Current trends in provision of computer qualifications do not appear to be keeping up with strong industry demand. For example, undergraduate acceptances into Computing courses at QUB and UU have been broadly flat in recent years.

8.26 DfE should seek to build capacity in each pathway to Computing skills and qualifications, including those for career changers and mothers returning to work. Taken across the piece, the growth in overall supply needs to be more in line with the growth in demand from the sector.

8.27 Some adaptations could be made to make courses more attractive to potential students. For example, a part-time online/hybrid option for Assured Skills Academies could de-risk this route for people currently in employment (an approach currently being piloted). Other changes could be made to make pathways more attractive to employers. For example, more front-loading of the off-the-job training in HLAs may make it more attractive for businesses to take

on new apprentices. Confirming apprenticeship funding over longer time periods would also help de-risk apprenticeships for employers, compared with the current year by year confirmation.

8.28 While MaSN is likely to remain a constraint on overall student numbers at QUB and UU, this does not prevent the universities from re-balancing across courses, to ensure that the qualifications in most demand in a 10X economy see growth, at the expenses of qualifications for which there is less demand and an over-supply of qualifiers. Furthermore, MaSN does not constrain the growth of Computing-related HE in FE.

Recommendation 6: DfE and Invest NI should take advantage of recent economic and working practice developments to facilitate an increase in the flow of experienced technical and commercial software talent re-locating to NI from GB, RoI and further afield.

8.30 Various campaigns have previously been undertaken to attract-in/attract-back talent to NI. However, some recent development have improved the chances of NI attracting in experienced talent:

- The sea-change in working patterns over the last two years has meant that it is now much more feasible for people originally from NI to return while keeping their current job.
- The increased scale of the software economy in Northern Ireland reduces the risks for re-locaters.
- Interest rate rises are continuing to put additional strain on housing affordability, especially in London and the South East of England: an area of advantage for NI.

8.31 While foreign software professionals earning more than £26,200 can be brought into NI through the Skilled Worker route, there remains a reluctance, particularly in small businesses, to undertake the cost and administration associated with this. Immigration is a reserved matter, but there is a role for DfE in understanding the difficulties faced by NI companies in arranging visas for non-UK staff, and lobbying UK Government where appropriate: ensuring that NI is not adversely impacted for Global Talent visas by the demise of Tech Nation.

8.32 Recognising the importance of access to talent, Invest NI is currently focused on a number of initiatives designed to deepen the local labour pool and encourage employers to explore alternative pathways to attract the staff they need to ensure continued growth. This includes a proposal to develop a new Talent Attraction programme, working in collaboration with industry to attract returning diaspora and new international talent, in areas of specific need within NI's economy.

Recommendation 7: The Software Alliance should promote the importance of the sector to the economy by: i) continuing to stress the need for policy clarity, direction and action for the software sector, and ii) considering how best to communicate the opportunities offered by the software sector to key target audiences.

8.34 The Software Alliance, an entity comprising new and established firms in the software space and supported by public policy makers, is an important and visible vehicle for promoting and developing the sector and its value to Northern Ireland economy.

8.35 As a relatively new body, and with a new Chief Executive recently appointed, the Alliance continues to work through its detailed priorities. Informed by its fieldwork, this study identifies two early action emphases for the Alliance to pursue: i) continuing to stress the need

for policy clarity, direction and action for the software sector, and ii) considering how best to communicate the opportunities offered by the software sector to key target audiences.

8.36 The study's consultations suggest that the current political uncertainty in NI is deterring investment to some extent, as well as creating deterring potential re-locators. The lack of a NI Executive has also added to the difficulties in agreeing and implementing significant effective policy change.

8.37 Some of the issues raised in this report – particularly around tackling the skills 'funnel' in the education system – will be extremely difficult to tackle. Although this study has revealed a shared recognition of issues holding back NI's software economy, and a strong appetite for change across a wide variety of stakeholders, the implementation of major change is never easy. In some cases, there may be arguments put forward for doing nothing, for making only minimal changes, or for delaying action: a 1X rather than 10X approach. It will be important to avoid the risk of difficult (but necessary) changes being avoided or watered down.

8.38 Industry leaders are the people with the most in-depth understanding of the issues that are currently constraining the growth of their businesses and the sector in NI. They should continue to ensure that the sector's 'voice' is heard loud and clear by policy-makers, while playing a very active part themselves in helping to deliver change.

8.39 A key challenge in boosting the supply of skills available will be changing the *perceptions* of coding and of the software sector in NI. Key audiences will include:

- School-age children and their parents
- Teachers
- Careers advisors
- Students at universities and FE
- Policy-makers
- Potential career changers and people returning to work after career breaks
- Potential re-locaters from GB, RoI and further afield.

8.40 An annual/biennial 'state of the sector' report is one option for helping to raise sector's profile. A 'who offers what' industry directory may also be an option for helping to raise awareness of potential employers and supply chain collaboration opportunities. Prior work by preceding sector development bodies (such as the Eastern Region Biotech Initiative and the Massachusetts (US) Technology Collaborative) point to what can be done)

8.41 However, it is likely that different messages, materials and channels will be appropriate for different audiences. Furthermore, there are various existing sector attractiveness efforts already underway.

8.42 The Software Alliance should play a leadership role in helping to focus and consolidate such efforts, leveraging resources from industry partners, government and the education sector, and in maximising the impact of targeted communications.

Remote Working

Recommendation 8: With partners such as the Software Alliance, Digital DNA, Ormeau Baths, Catalyst and others, DfE should seek to ensure that NI's remote tech workers are, and remain, well-connected into the local software ecosystem in NI.

8.44 Anecdotal evidence from this and other studies[37] suggests that, following the change in working practices accelerated through the pandemic lockdowns, significant numbers of tech professional are choosing to work remotely – e.g. living in NI and working from home for a business based in London, Cambridge or the US. These people are typically the more experienced professionals that are in particular demand by NI-based software businesses.

8.45 Ensuring that these people become and/or remain well-connected with others in the local software ecosystem will help provide opportunities for peer-to-peer knowledge sharing and will increase the chances of them choosing to join, or re-join, a local NI business at some point in the future. It may also facilitate the creation of new start-up ventures, through 'managed serendipity' bringing together potential co-founders in networking events etc.

8.46 There is no single organisation in NI with an obvious remit to take the lead in reaching out to these remote workers: the Software Alliance, for example, is based on organisation memberships rather than individual memberships. We therefore suggest that DfE leads on this action, drawing on ecosystem partners such as Digital DNA, Ormeau Baths and Catalyst as well as the Software Alliance. Executed well, this is an area in which NI could take a real lead in the UK.

Recommendation 9: DfE and Invest NI should facilitate the spread of best practice in remote working approaches across the software sector.

8.48 The shift to sustained remote/hybrid working has been a fundamental change over the last couple of years, with the software sector leading the way. The study's consultations confirmed that remote/hybrid workers is generally popular with employees, who value the flexibility it provides as well as the reduction in commuting. However, it comes with potential downsides, particularly in the risk of some people feeling isolated, in inducting new recruits into company culture and systems/processes, in the personal development of younger staff and inter-generational sharing of knowledge, and in terms of the innovations resulting from 'water-cooler moments'.

8.49 Managing remote/hybrid working effectively has become a critical organisational competence. There is plenty of practical experience of 'what works', and there is scope for NI's software sector businesses to learn from each other in optimise their own remote/hybrid working management practices and tools.

8.50 DfE and Invest NI could help diffuse best practice through convening events and developing case studies, for example. We would see the best practice information and insights mostly coming from industry players, with DfE and Invest NI using their convening power to facilitate knowledge sharing. The software sector has historically led the way in remote/hybrid working, and such good practice could also be shared to the benefit of many other industry sectors in NI.

Pipeline of Indigenous Start-Ups/Scale-Ups

Recommendation 10: Supported by DfE and industry, QUB and UU should embed entrepreneurship and management education alongside relevant subject areas for the

[37] See, for example, **Assessing the UK's Regional Digital Ecosystems**, Steer, 2021

software sector, and facilitate 'collision' opportunities between potential future co-founders.

8.52 Drawing on best international practice in tertiary education of computing students (recommendation 3), universities could help further highlight entrepreneurship as a career option to undergraduate and postgraduate students – whether after graduation or at some point in the future, and provide some of the knowledge and skills needed in setting up a business. This is something that would be relevant to all students, but would perhaps be particularly valuable for those with software skills, given the criticality of software for many new knowledge economy businesses.

8.53 Such initiatives can also help showcase indigenous NI start-ups/scale-ups – raising students' awareness of these companies as potential employers.

8.54 Universities also play a key role in informally bringing together tech co-founders (witness Hewlett Packard, Google, Facebook etc.). Cross-disciplinary events can help provide 'collision' opportunities between potential future co-founders – e.g. linking a business student who has an idea for a tech business with a computing student with the skills to develop a prototype of the idea.

8.55 UU is already making progress in this area: all undergraduate students in computing on the Belfast Campus will be taking a new "Innovation in Society" module from September 2023. This is intended to help address communication and team working skills, and to help develop the entrepreneurship and intrapreneurship skills of students.

Recommendation 11: DfE and Invest NI should put renewed emphasis on support for entrepreneurship and indigenous start-ups and scale-ups in software-intensive activities.

8.57 NI's software sector has seen tremendous growth over the last 20 years, thanks to a combination of FDI and the growth of indigenous firms such as Kainos, FD Technologies and FinTrU. However, the study's consultations and desk research suggest that there is a need to boost the pipeline of start-ups and scale-ups, who are finding it hard to attract and retain talent in the current very hot market for software jobs. There was also some criticism of the funding for successful support programmes such as Ignite being stopped.

8.58 Re-energised support from DfE and Invest NI for start-ups and scale-ups could help amplify the advice and support available from others such as Ormeau Baths and Catalyst. It could help, for example, to:

- link start-ups and scale-ups with mentors who have 'been there, done that'
- facilitate links between small businesses and the FE sector – raising awareness of the support that FE can provide in this area
- raise awareness among small businesses of the universities' business innovation support offerings.

Towards Implementation

8.59 Should DfE and partners accept this study's recommendations, their implementation will be challenging given funding constraints and the complex nature of some of the issues to be addressed. Some recommendations could be implemented relatively quickly, while others could take some years to be fully realised.

8.60 DfE will need to consider how best to integrate any resulting actions with existing governance and management arrangements, such that sustained momentum is built up in addressing the issues highlighted by this study. This will maximise the considerable contribution that NI's software economy will make towards the realisation of the 10X Vision.

A In-Scope SIC and SOC Codes

A.1 This annex sets out the SIC and SOC codes which we have used as a proxy for the 'software sector' or 'software jobs' in this study. The level of SIC/SOC for which data is available varies depending on the source. The more detailed codes have been used where the data is available. For SOC occupation data, some sources still use the SOC2010 coding rather than the more recent SOC2020 coding.

SICs

2-digit	3-digit	4-digit	5-digit
62 : Computer programming, consultancy and related activities	582: Software publishing; 620: Computer programming, consultancy and related activities; 631 : Data processing, hosting and related activities; web portals	5821 : Publishing of computer games; 5829 : Other software publishing; 6201 : Computer programming activities; 6202 : Computer consultancy activities; 6203 : Computer facilities management activities; 6209 : Other information technology and computer service activities; 6311 : Data processing, hosting and related activities; 6312 : Web portals	58210 : Publishing of computer games; 58290 : Other software publishing; 62011 : Ready-made interactive leisure and entertainment software development; 62012 : Business and domestic software development; 62020 : Computer consultancy activities; 62030 : Computer facilities management activities; 62090 : Other information technology and computer service activities; 63110 : Data processing, hosting and related activities; 63120 : Web portals

SOCs

SOC2010		SOC2020	
3-digit	**4-digit**	**3-digit**	**4-digit**
213 Information Technology and Telecommunications Professionals 313 Information Technology Technicians	1136 Information technology and telecommunications directors 2133 IT specialist managers 2134 IT project and programme managers 2135 IT business analysts, architects and systems designers 2136 Programmers and software development professionals 2137 Web design and development professionals 2139 Information technology and telecommunications professionals n.e.c. 3131 IT operations technicians 3132 IT user support technicians	213 Information Technology Professionals 214 Web and Multimedia Design Professionals 313 Information Technology Technicians	1137 Information technology directors 2131 IT project managers 2132 IT managers 2133 IT business analysts, architects and systems designers 2134 Programmers and software development professionals 2135 Cyber security professionals 2136 IT quality and testing professionals 2137 IT network professionals 2139 Information technology professionals n.e.c. 2141 Web design professionals 2142 Graphic and multimedia designers 3131 IT operations technicians 3132 IT user support technicians 3133 Database administrators and web content technicians 3573 Information technology trainers

Descriptions of In-Scope SOC Codes

SOC2020 code	Description
1137 Information technology directors	Information technology directors plan, organise, direct and co-ordinate the work and resources necessary to provide and operate IT infrastructure and services, including networks, devices, servers and software that runs on the infrastructure within an organisation. IT programme managers and directors direct and provide technical oversight to particular IT programmes of a discrete duration and/or budget.
2131 IT project managers	IT project managers manage, coordinate and technically supervise specific IT projects of a discrete duration and/or budget.
2132 IT managers	IT managers plan, organise, manage and coordinate the provision of IT services and functions in an organisation.
2133 IT business analysts, architects and systems designers	IT business analysts, architects and systems designers provide advice on the effective utilisation of IT and design IT systems in order to meet the business objectives or to enhance the business effectiveness of the organisation.
2134 Programmers and software development professionals	Programmers and software development professionals design, develop, test, implement and maintain software systems on a range of platforms in order to meet the specifications and business objectives of the information system; they also design and develop specialist software e.g. for computer games.
2135 Cyber security professionals	Cyber security professionals design, implement, test and maintain cyber security systems and track, investigate and analyse data linked to cybercrime.
2136 IT quality and testing professionals	IT quality and testing professionals test the quality of IT software, systems and computer games and identify and recommend solutions to problems and improvements that could be made.
2137 IT network professionals	IT network professionals design, set up and maintain computer networks, support the network users and fix problems which arise.
2139 Information technology professionals n.e.c.	Job holders in this unit group perform a variety of tasks not elsewhere classified in MINOR GROUP 213: Information Technology Professionals.
2141 Web design professionals	Web design professionals design, develop and maintain websites and web and mobile applications to meet a client's specified requirements.
2142 Graphic and multimedia designers	Graphic and multimedia designers use illustrative, sound, visual and multimedia techniques to convey a message for information, entertainment, advertising, promotion or publicity purposes, and create special visual effects, 3D models and animations for computer games, film, interactive and other media.
3131 IT operations technicians	IT operations technicians are responsible for the day-to-day running of IT systems and networks including the preparation of back-up systems, and for performing regular checks to ensure the smooth functioning of such systems.
3132 IT user support technicians	IT user support technicians are responsible for providing technical support, advice and guidance for internal/external users of IT systems and applications, either directly or by telephone, e-mail or other network interaction.

SOC2020 code	Description
3133 Database administrators and web content technicians	Database administrators and web content technicians administer, maintain and provide user support for databases and websites and assist in the design and development of databases; and monitors social media sites for posts and comments on behalf of companies.
3573 Information technology trainers	Information technology trainers provide instruction in the use of computers for professional and personal purposes and advise on, plan and organise IT training within industrial, commercial and other establishments.

Source: SOC 2020 Volume 1: structure and descriptions of unit groups, ONS

B List of Study Consultees

Consultee	Organisation
Mark McCormack	Aflac Northern Ireland
Trevor Graham	Ampliphae
Niall Haslam	Apex Fintech Solutions
Ross Hompstead	ASOS
Gavin Woods	Aurion Learning
Eamonn Brankin	Belfast Metropolitan College
Steve Orr	Catalyst
Terry Canning	Cattle Eye
Angela McGowan	CBI
Michael McEnery	Council for the Curriculum Examinations and Assessment
Fiona Browne	Datactics
Morris Logan	Deloitte
Christopher Sloan	Deloitte
Mark Lee	Department for the Economy
Raymond Caldwell	Department of Education
Joan Cassells	Department of Education
Gareth Edge	Department of Education
William Revels	Digital Catapult
Simon Bailie	Digital DNA
John Kennedy	Education and Training Inspectorate
Tara Simpson	Instil Software
Karen Bradbury	Invest NI
Conor Dunbar	Invest NI
George McKinney	Invest NI

Consultee	Organisation
Daniel Loughlin	IRP Commerce
Allen Houston	Johnson Controls
Tom Gray	Kainos
Tony Marron	Liberty-IT
Aodheen Dougan	Manufacturing NI
Barry Smyth	MCS Group
Nigel Cunningham	Microsoft
Kieran McCorry	Microsoft
Fergal Tuffy	NW Regional College
Claire Halliday	Ormeau Baths
Ciaran Connolly	ProfileTree
Philip McDonough	PwC
Richard Newman	PwC
David Crozier	Queen's University Belfast
Dave Cutting	Queen's University Belfast
Stephen Fawl	Randox
Chris Wallace	Rapid 7
Phil Morrow	Retinize
Tom Houston	Sentireal
Dermot Kerr	Smart Manufacturing Data Hub
John Healy	Software Alliance, and ex Allstate
Michael Gould	Software Alliance, and PDI
Irene Bell	Stranmillis University College
Jonathan Heggarty	Stranmillis University College
Martin McKay	Texthelp
Michael McClelland	Totalmobile Ltd
Johnny Wallace	Ulster University
Aiden McCaughey	Ulster University
Lorna McAdoo	Version 1

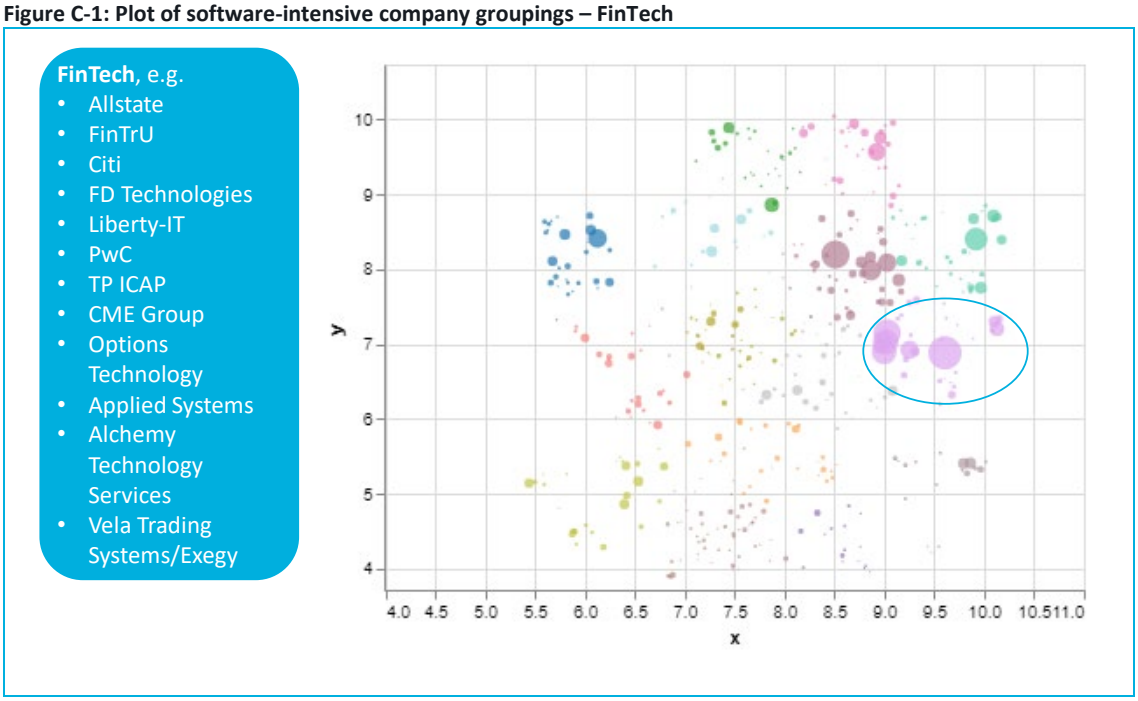
C Company Groupings Charts

C.1 This annex contains the plots arising from the analysis of company groupings, applying a k-means cluster algorithm to text scraped from the companies' websites.

C.2 In the charts below, each of the companies is assigned to one of 15 groupings (separately coloured), visualised in two dimensions with the marker size being proportional to the indicative relevant employment in NI.

C.3 The x and y axes in the charts are abstract dimensions derived from the UMAP dimensionality reduction algorithm, calculated such that companies with similar activities are visualised close together in two dimensions. The axes can be thought of as simplified summaries of the original data, distilling it into two aspects that capture the main patterns. The distances between points on the chart reflect their similarities in the original data, even though that data had many more details. Clusters, or groups of companies that are close together, indicate that these companies share common characteristics.

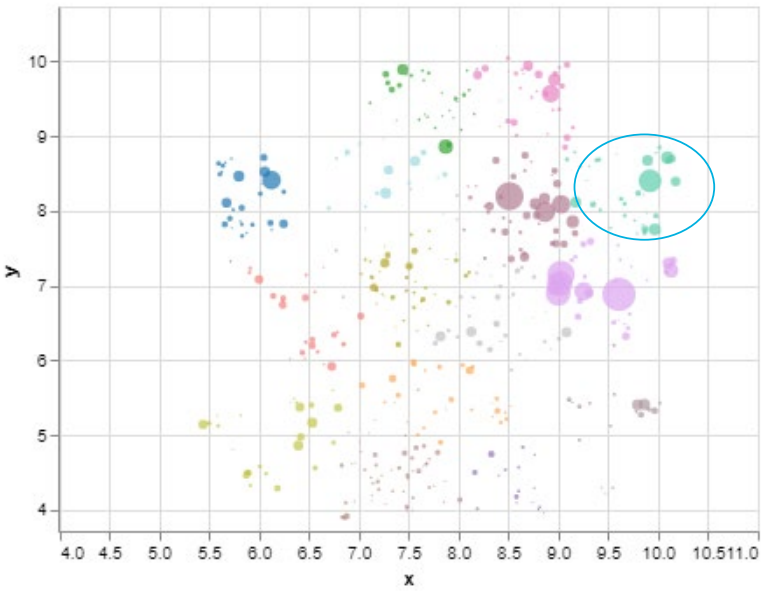
Figure C-1: Plot of software-intensive company groupings – FinTech



Source: DMS Research & Consulting

Figure C-2: Plot of software-intensive company groupings – Data Analytics

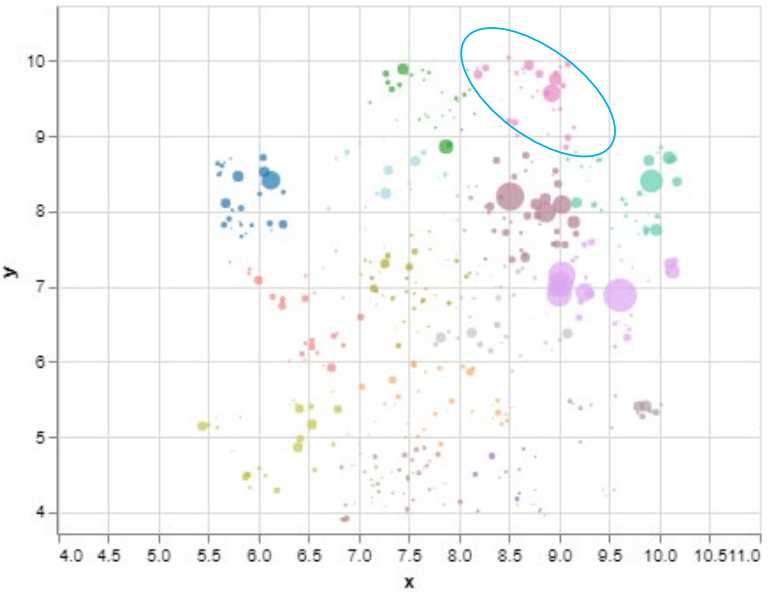
Data Analytics, e.g.
- Seagate
- Deloitte
- Data Intellect
- IBM
- Diaceutics
- Datactics
- EY
- Automated Intelligence
- Anaeko
- Wandisco
- ISx4
- Analytics Engines
- Sonrai Analytics



Source: DMS Research & Consulting

Figure C-3: Plot of software-intensive company groupings – Cyber

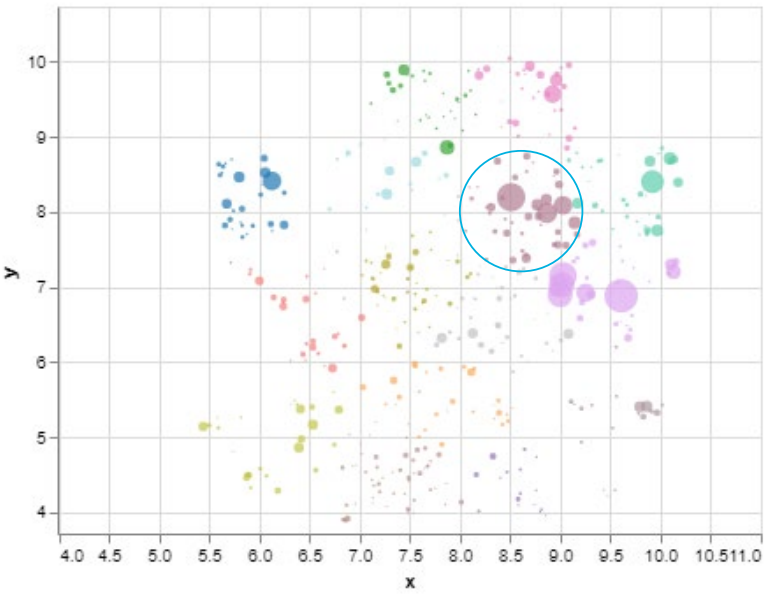
Cyber, e.g.
- Rapid7
- Proofpoint
- Metacompliance
- Imperva
- Kigen
- Anomali
- Skurio
- Contrast Security



Source: DMS Research & Consulting

Figure C-4: Plot of software-intensive company groupings – Digital Transformation 1

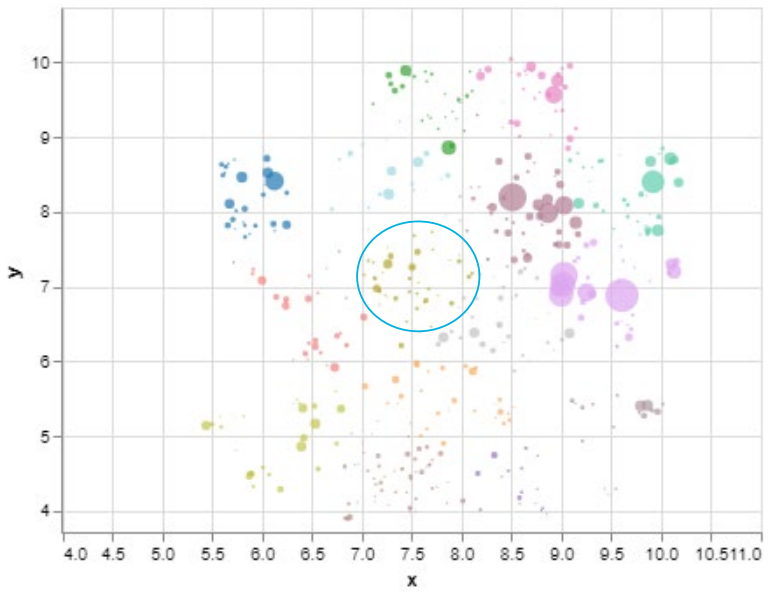
Digital Transformation 1, e.g.
- Kainos
- Fujitsu
- Version 1
- Expleo
- Telefonica Tech NI
- I.T. Alliance
- Civica NI
- Unosquare



Source: DMS Research & Consulting

Figure C-5: Plot of software-intensive company groupings – Digital Transformation 2

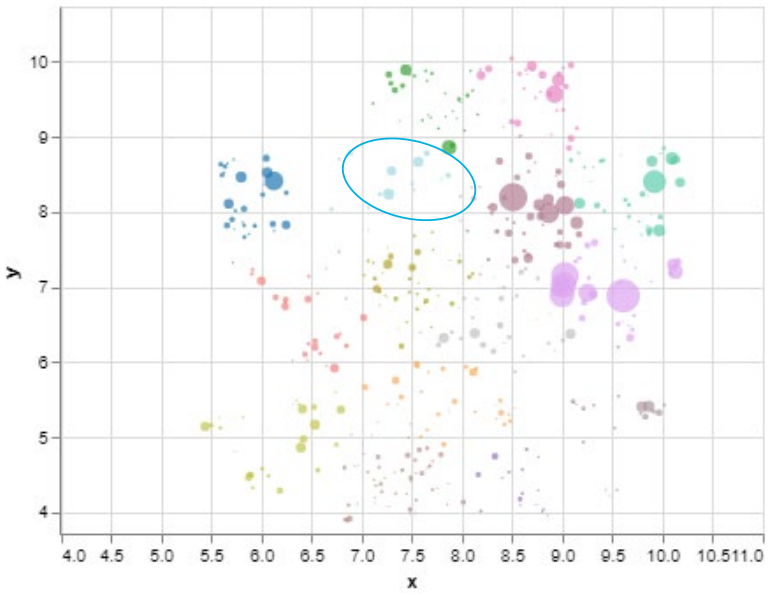
Digital Transformation 2: e.g.
- Totalmobile
- Foods Connected
- Blue Zinc IT
- NiSoft
- Smashfly Technologies
- Elemental (Access Group)
- Allsop Consulting
- Auditcomply
- Fieldmotion



Source: DMS Research & Consulting

Figure C-6: Plot of software-intensive company groupings – Digital Transformation 3

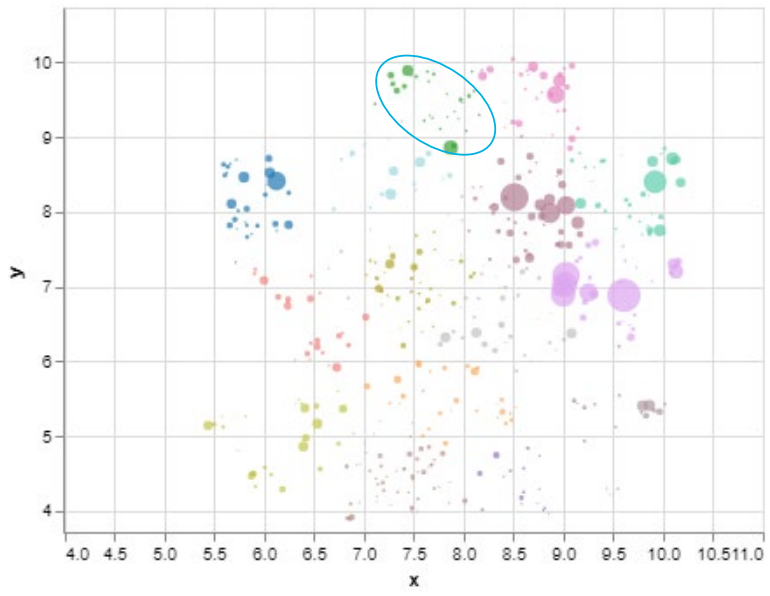
Digital Transformation 3, e.g.
- Pinnacle Computing
- Equiniti ICS
- Xperience Group
- Xerox IBS
- Pentagon Solutions



Source: DMS Research & Consulting

Figure C-7: Plot of software-intensive company groupings – IT and Telecoms Service Providers

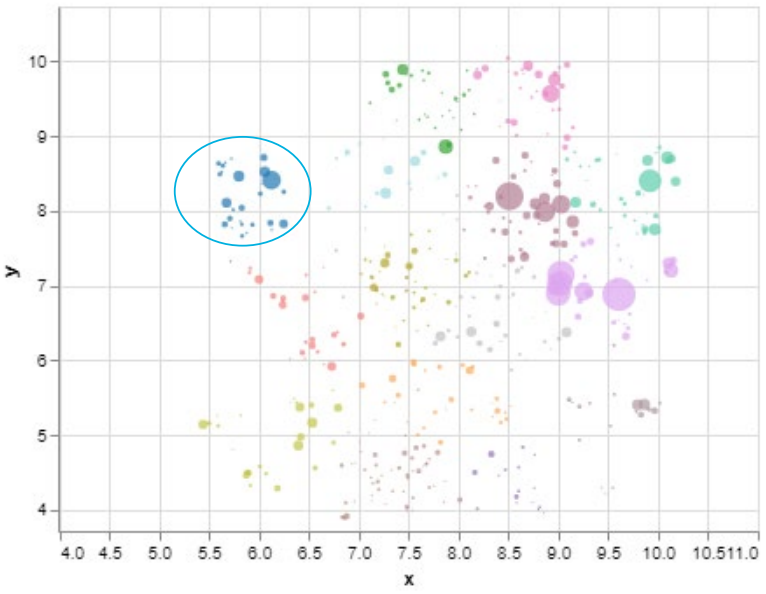
IT & Telecoms Service Providers, e.g.
- BT
- Microsoft
- Endeavour Information Solutions
- Sysco Software
- Meritcom
- Codec
- Nimbus



Source: DMS Research & Consulting

Figure C-8: Plot of software-intensive company groupings – Sensing, Control & Automation

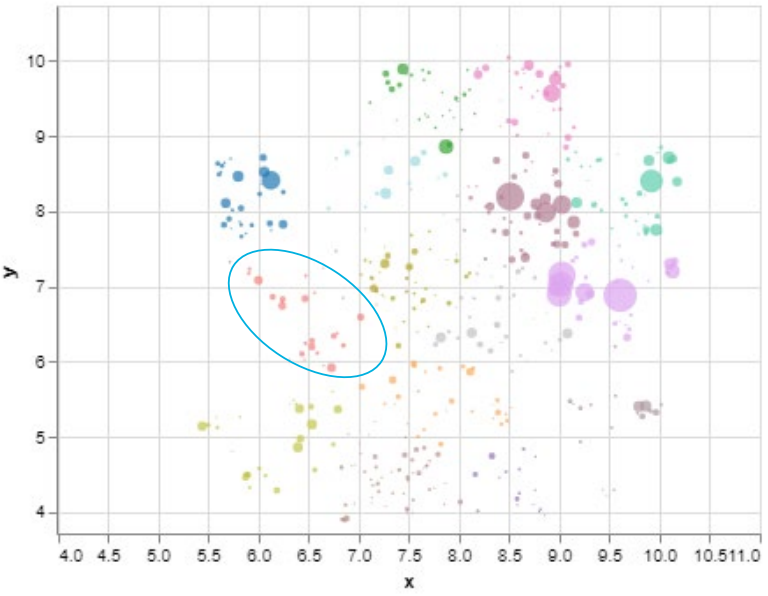
Sensing, Control & Automation, e.g.
- Sensata
- GE Grid Solutions
- Johnson Controls
- TES Group
- Globeweigh
- ATC Systems
- Pneutrol
- FAST Technologies
- AW Control Systems
- Axon Power & Control



Source: DMS Research & Consulting

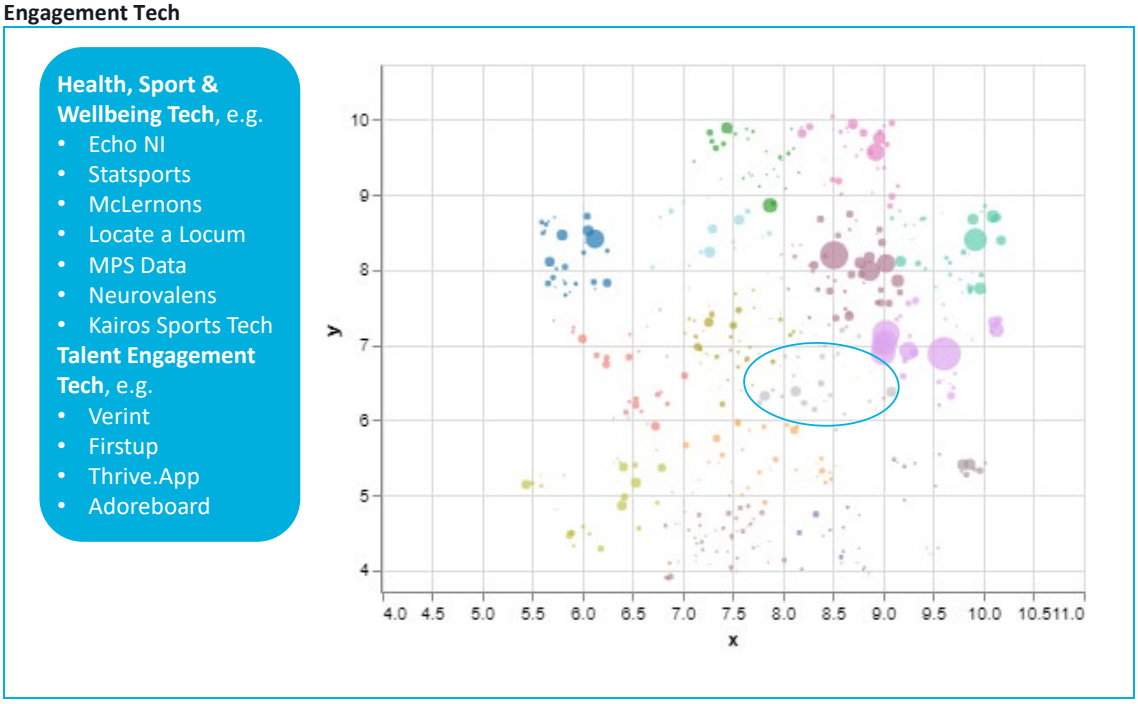
Figure C-9: Plot of software-intensive company groupings – Retail Tech

Retail Tech, e.g.
- ASOS
- ShopKeep
- Henderson Technology
- Selazar
- VME Retail Systems
- Bixtech Software
- AirPOS
- The EPOS Bureau
- Haru



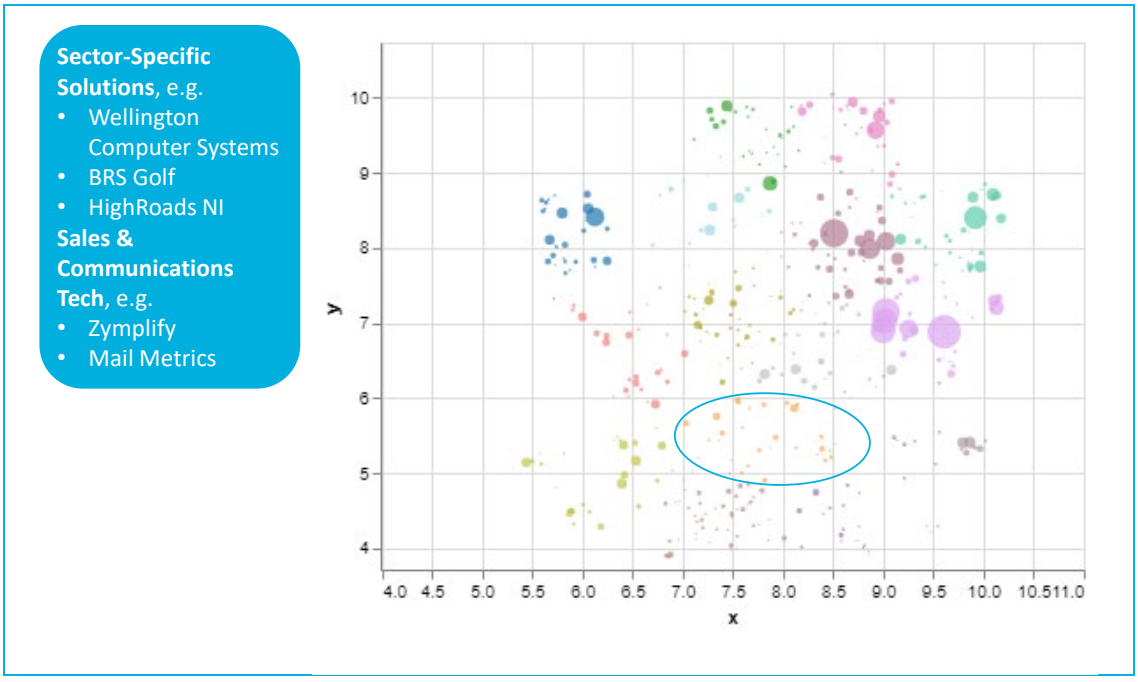
Source: DMS Research & Consulting

Figure C-10: Plot of software-intensive company groupings – Health, Sport & Wellbeing Tech and Talent Engagement Tech



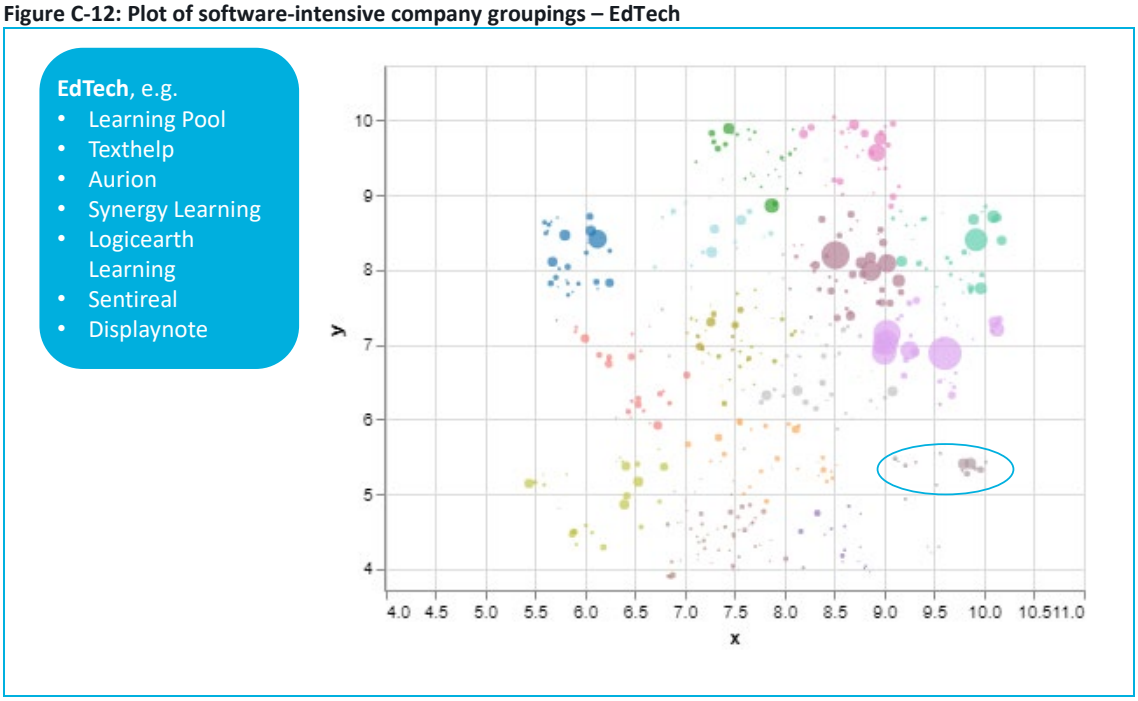
Source: DMS Research & Consulting

Figure C-11: Plot of software-intensive company groupings – Sector-Specific Solution and Sales & Communications Tech



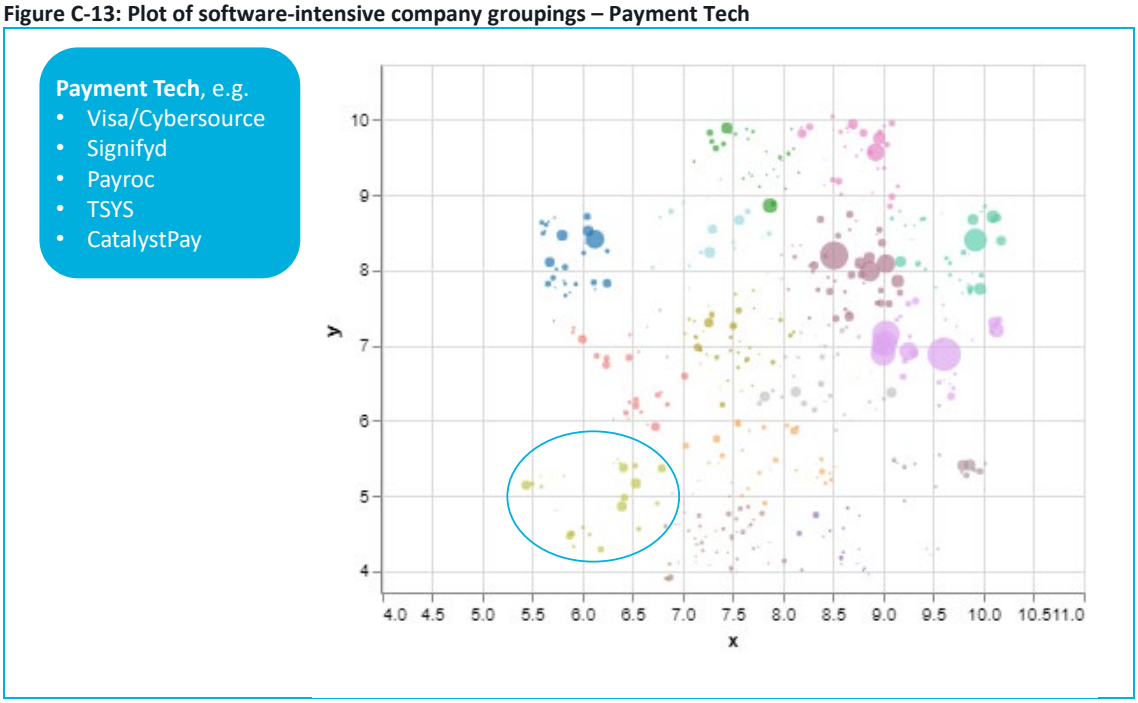
Source: DMS Research & Consulting

Figure C-12: Plot of software-intensive company groupings – EdTech



Source: DMS Research & Consulting

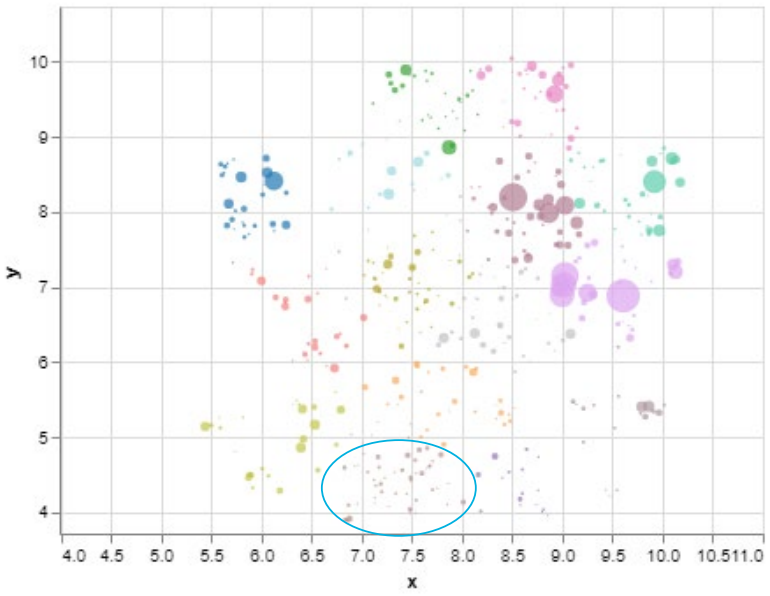
Figure C-13: Plot of software-intensive company groupings – Payment Tech



Source: DMS Research & Consulting

Figure C-14: Plot of software-intensive company groupings – Digital Marketing

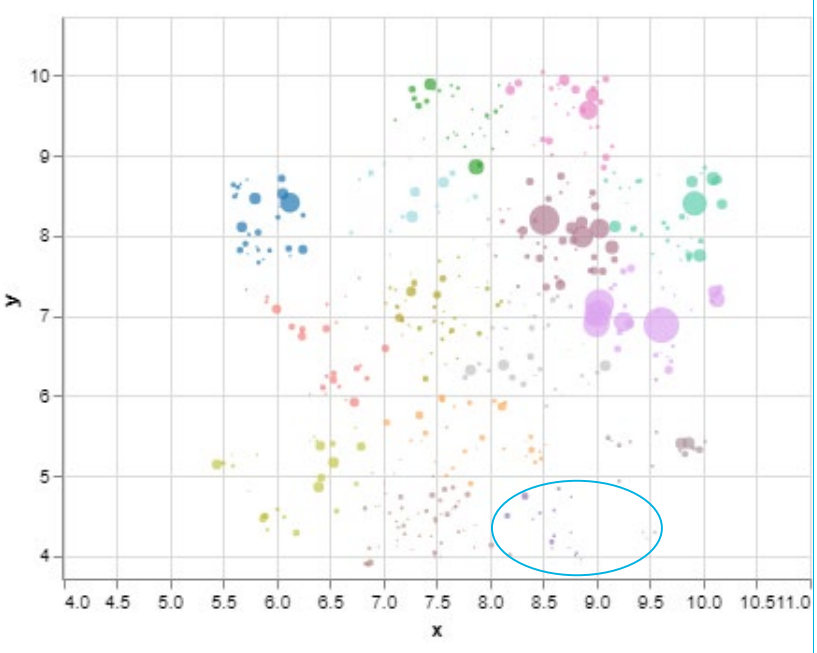
Digital Marketing, e.g.
- Magnite
- Genesis Advertising
- Flint Studios
- Profile Tree
- Dawson Andrews
- Origin Digital
- WebsiteNI
- Icon Creative



Source: DMS Research & Consulting

Figure C-15: Plot of software-intensive company groupings – Entertainment and Immersive Tech

Entertainment and Immersive Tech, e.g.
- NBC Universal
- Yellow Moon
- Hypixel Studios
- Retinize
- Ka-Boom
- Go Testify
- Rocket Flair Studios
- Humain



Source: DMS Research & Consulting

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+44 (0)113 389 6400

London
28-32 Upper Ground
London, SE1 9PD
+44 (0)20 7910 5000

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