Industry 4.0 and its Potential Impact on Employment Demographics in the UK

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Abstract. Since 2011, the manufacturing sector has been subject to a paradigm shift referred to as Industry 4.0, or the 4th Industrial Revolution. Industry 4.0 is concerned with cyber-physical systems for production engineering that enable the interconnected smart factories of the future. Its associated emerging technologies will bring along significant changes with respect to manufacturing processes and supply chains, allowing manufacturers to maintain their competitive edge in a rapidly changing globalized world. A recent study revealed that in 2016 only 8% of the UK manufacturers had a significant understanding of the term Industry 4.0, and that 56% had little or no understanding of it. However, 59% believed Industry 4.0 would have a big impact on the manufacturing sector. Most of the ongoing research on Industry 4.0 is concerned with the actual development of cyber-physical systems, cloud manufacturing, cybersecurity, and big data analytics. This study investigates the potential impact of Industry 4.0 on future unemployment, and the need for a highly responsive education system to develop the Industry 4.0 workforce of near tomorrow. At present, educational systems appear not to be adapting fast enough to respond to future labour demands imposed by Industry 4.0. If not addressed, this challenge may result in the required skills being undersupplied, thereby fuelling disparities between labour supply and demand, which consequently may cause unemployment levels to rise. This highlights the need to further investigate this situation and to identify and fulfil the educational requirements underlying future employment in a post Industry 4.0 era.

Keywords. Industry 4.0, Cloud Manufacturing, Employment, Workforce, Engineering Education, Global Competitiveness.

1. Introduction

Europe is thought to be on the brink of a fourth industrial revolution, namely Industry 4.0 (I4). This revolution may be regarded as “the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry” [1]. Objectives such as the ability to produce a batch size of one whilst achieving economies of scale comparable to those of mass production [2], are often used to communicate and motivate I4. It will rely upon enabling technologies, such as those described [3] and displayed in Figure 1. These technologies make I4 distinct from previous industrial paradigms, bringing about new requirements for the manufacturing workforce.

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Research currently focuses on the microeconomic issues surrounding I4, such as the benefits of cyber-physical systems and smart factories for single company. The research

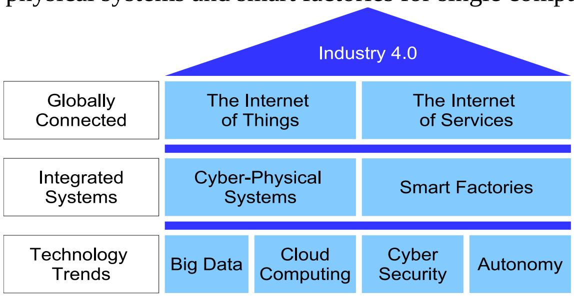

Figure 1. A vision of Industry 4.0, modified from the work originally presented in [3]

reported in this paper takes a macroeconomic stance, questioning ramifications of I4 on future education and unemployment in the UK. Comparative measures are used to identify the relative readiness of the UK in relation to Germany, France and Italy. In doing so, this research attempts to answer the following question: *"Is the UK prepared for the step-change that is necessary to adapt and re-train the manufacturing workforce in response to the new requirements brought about by I4?"*

2. Literature Review

The UK's readiness for I4 in relation to other economies is not clear. There has been limited UK investment in education and training in relation to I4 [4]. Instead, investment has targeted research and development into new technologies. Lack of responsiveness from the UK regarding I4 could lead to a diminishing competitive advantage.

2.1. The relationship Between Technological Unemployment and Education

There is ongoing debate about whether technological advancement and, in particular, automation leads to a net increase in unemployment [5]. Previously, unemployment levels have typically recovered after a period of adjustment [6], allowing for new and unforeseen jobs to emerge, education to adapt and retraining to commence. Discussion is now focusing on the types of job that are likely to be displaced by computerisation [7]. Consensus is emerging that routine jobs with lower creative or empathetic requirements are most at risk [8]–[10]. Interestingly, Frey and Osborne [8] estimated that machinists have a 65% probability of being displaced by computerisation. A factor that is widely acknowledged by both sides of this debate is that there is a need to develop new skills within key sectors, such as manufacturing [11].

Frey and Osborne [8] estimated the probability of computerisation for 702 detailed occupations. They concluded that 47% of all US employment is in a high-risk category, compared to only 9% in the UK. The same study identified that production work was high-risk and that there is a strong negative correlation between risk of computerisation, and wages and educational attainment. These findings are in stark contrast to the work Arntz et al. [9], who forecast 35% and 10% for the US and UK, respectively. A Price Waterhouse Cooper (PWC) report [10] suggests that approximately 30% of jobs within the UK manufacturing sector are in the high-risk category (38% in the US). The discrepancies between these figures have been attributed to methodological differences;

some studying an entire job-role role and some focusing on specific tasks within a job-role [10].

As manufacturing work continues to shift from manual labour to the programming and control of high-performance machines [1], the skills deficit of the workforce may increase as I4 develops. Studies support the hypothesis that computerisation is polarising the skill demand in the labour market [12]. Evidence suggests that non-routine manual labour is broadly unaffected, non-routine cognitive tasks have been complemented by computers, but middle-skilled routine tasks have been substituted by computers.

2.2. Issues Facing Educations Systems as a Result of Industry 4.0

There is a discrepancy between the education pursued by students and the qualifications sought by employers. Forecasts suggest that the EU could experience an 825,000 shortfall in ICT professionals by 2020 [1]. The UK's Education and Employers Taskforce identified lack of clarity and rapid change in the requirements of the labour market as a recurring theme [13]. However, this is not just a problem in the UK. Bardhan et al. [14] studied how the US higher education system responds to the pull demand of the labour market. It was found that higher education was weakly responsive to short-term signals and moderately responsive to long-term trends. The education sector faces significant challenges in: (i) identifying what to teach people to meet the future demands of the labour market, and (ii) making education responsive enough to match supply with demand before skills become obsolete. The advent of massive open online courses (MOOCs) and engineering education that focuses on 'learning how to learn' across different countries and cultures [4] is a sign that this is starting to be addressed.

3. Indicators of Industrial and Educational Readiness for I4

Indicators from multiple data sources have been collated and processed to assess the readiness of nations to react to I4. The methodology of this research exploits indicators relating to the manufacturing sector, readiness for innovation, ICT utilisation and key sector ratios. Information has been gathered for France (FRA), Germany (DEU), Italy (ITA) and the United Kingdom (UK), as these are the four largest European manufacturing economies [15]. No attempts have been made to manipulate data beyond its raw format, covert or rescale data, or create new metrics from multiple sources. An exception to this is the forming of ratios, such as dividing the gross value added by the number of people employed within a sector. It is beyond the scope of this study to assign relative importance to each metric. Countries are ranked for each metric and their ranks are summed across all metrics. A larger sum of ranks represents better performance.

3.1. Manufacturing Sector Size, Productivity and Level of Routine

It is assumed that inclusion of new technologies and the heightened use of ICT within manufacturing (brought on by I4) will require widespread retraining and additional education. Countries adding considerable manufacturing value with a small workforce are likely to have already achieved relative manufacturing excellence, and have a strong likelihood of having embraced automation and ICT to improve efficiency. Germany is the clear leader in this regard, followed by the UK, France and then Italy. The UK has the lowest dependency on high and medium routine in manufacturing tasks. If future technological unemployment is at its most severe amongst job-roles with routine tasks, the UK is well-positioned to transition into I4 from an employment standpoint.

Table 1. Productivity and levels of routine in manufacturing. Gross value added per head derived from [16], [17], levels of routine in manufacturing [18]. Ranks in brackets.

	FRA	DEU	ITA	UK
Gross value added per head of manufacturing workforce (2014), trillions USD/person	103.32 (2)	106.87 (3)	77.56 (1)	108.81 (4)
High & medium routine in manufacturing tasks (average 2000-11), %	72 (2)	60 (3)	84 (1)	57 (4)
Sum of Ranks	**4**	**6**	**2**	**8**

3.2. ICT Adoption, Proficiency and Value Added

ICT is viewed as a key enabler in I4. The extent and speed at which industry can exploit information and communication technologies within manufacturing is likely to be governed by the existing infrastructure, ICT advancement and skill-sets. To quantify these for each nation, four metrics are used in Table 2. The Networked Readiness Level (NRL), as reported in [19], represents the tendency of a nation to exploit information and communications technology. In a global, hyper-connected and highly competitive market (as envisaged in I4), the ability to add value to products and services through ICT is paramount. Hence, gross value added in ICT is given. The level of demand for ICT specialists is given as an indication advancement, but also of the potential employment rates and wages for ICT professionals in each country. Finally, a country's ability to generate new ICT technologies is given. In I4, ICT and connectedness will be essential. Therefore, creating value from ICT innovation will represent a competitive advantage.

The UK performs favourably in all categories except for new generation of ICT technologies. In this regard, both France and Germany considerably outperform the UK. The UK's most comprehensive advantage lies in its ability to add value through ICT. Other factors are more closely contested, making this a differentiating factor that the UK could use in the pursuit of high-value I4 business models.

Table 2. Economic indicators of an advanced and stable ICT workforce. Networked readiness level [19], ICT value added [20], demand for ICT specialists [21], new generation of ICT technologies [22]. Ranks in brackets

	FRA	DEU	ITA	UK
Networked readiness level (2016)	5.3 (2)	5.6 (3)	4.4 (1)	5.7 (4)
ICT value added (2011), % of value added	5.1 (2)	5.1 (2)	4.9 (1)	7.4 (4)
Demand for ICT specialist skills (2016), %	~2.6 (1)	~3.2 (3)	~2.7 (2)	~3.8 (4)
New generation of ICT technologies (2015)	4.97 (4)	3.81 (3)	0.60 (1)	3.21 (2)
Sum of Ranks	**9**	**11**	**5**	**14**

3.3. Readiness for Innovation

The transition to I4 will require innovation and a national policy that promotes technological advancement. Perhaps the most detailed quantitative data relating to readiness for innovation is compiled by the OECD in their Science, Technology and Innovation Outlook [23]. Table 3 contains 22 indicators for innovation system performance. These represent the quality of universities and public research, innovation in firms, entrepreneurship, ICT infrastructure, networks and connectedness and skills for innovation. The UK has the greatest sum of ranks across all 22 categories, performing favourably in tertiary education, academic institution quality and research, ease of entrepreneurship, connectedness, E-Government readiness and international co-patenting. Relatively speaking, it underperforms in R&D expenditure, employment in science and technology, corporate R&D investment and triadic patent families.

Table 3. Key indicators of national innovation system performance [23]. Scores are scaled to the range 0-200 amongst all OECD participants.

	FRA	DEU	ITA	UK
Public R&D expenditures (per GDP)	129.28	147.58	67.99	86.25
Top 500 universities (per GDP)	86.58	106.69	101.75	121.03
Publications in the top-quartile journals (per GDP)	87.06	88.38	81.38	148.37
Business R&D expenditure (per GDP)	110.93	133.55	51.79	95.62
Top 500 corporate R&D investors (per GDP)	124.56	120.20	86.47	116.85
Triadic patent families (per GDP)	124.60	151.71	86.42	111.19
Trademarks (per GDP)	102.08	105.78	88.26	105.32
Venture capital (per GDP)	113.47	96.10	12.47	112.32
Patenting firms less than 5 years old (per GDP)	83.46	103.20	71.01	111.11
Ease of entrepreneurship index	103.24	98.69	145.85	200.00
Fixed broadband subscribers (per population)	164.17	154.98	80.49	155.32
Wireless broadband subscribers (by population)	86.19	65.62	95.80	100.36
Networks (autonomous systems) (by population)	28.31	49.69	28.99	84.75
E-government readiness index	149.47	106.12	70.20	174.81
Industry-financed public R&D expenditures (by GDP)	72.44	173.70	19.67	72.16
Patents filed by universities and public labs (per GDP)	127.79	100.00	50.54	113.85
International co-authorship (%)	99.45	98.25	77.24	90.76
International co-patenting (PCT patent applications)(%)	87.08	69.12	52.47	104.55
Adult population at tertiary education level (%)	79.72	68.53	13.52	110.19
15-year-old top performers in science (%)	100.10	144.12	70.64	130.75
Doctoral graduation rate in science and engineering	127.09	135.40	88.17	138.38
S&T occupations in total employment (%)	124.38	125.82	98.83	85.00
Sum of Ranks	**60**	**63**	**29**	**68**

3.4. Key Sector Ratios

I4 requirements within manufacturing must be met with an agile and well-resourced education sector. The envisaged increase in the need for ICT experts in manufacturing will require a buoyant ICT sector. The need for integrating new technologies and scientific innovation will require a thriving science and technology community. The balance between manufacturing, ICT, education, and science and technology workforces are given in (Table 4). A nation with a large manufacturing workforce, with high routine intensity, and a comparatively small education, ICT or science and technology sector will face more severe obstacles in transitioning into I4. In terms of balance between key sectors, the UK is better positioned that its European counterparts.

Table 4. Key ratios between sector workforces. Manufacturing workforce [16], ICT workforce [16], education workforce [24], science and tech workforce [16]. Ranks in brackets.

	FRA	DEU	ITA	UK
Manuf. / ICT (2013)	3.32 (3)	6.11 (2)	6.73 (1)	2.03 (4)
Manuf. / Education (2013)	8.05 (3)	11.79 (1)	11.77 (2)	6.04 (4)
Manuf. / Science & Tech. (2013)	0.70 (3)	1.34 (2)	1.40 (1)	0.53 (4)
Sum of Ranks	**9**	**5**	**4**	**12**

4. Concluding Remarks

This paper has collated a metrics in relation to the manufacturing sector, readiness for innovation, ICT capability and balance between workforces in key sectors. By ranking the four largest manufacturing economies across each metric, this research has created new insights into the readiness of European nations to respond I4. Through the sum of its ranks, the UK (102) has been shown to be well-positioned in relation to France (82), Germany (85) and Italy (40). However, it must be acknowledged that no relative importance has been assigned to the metrics at this stage. The future of this research lies in the further development of these indicators by incorporating a wider array of sources and identifying appropriate weightings for parameters. Further research is needed to quantify the responsiveness of education to labour demands. This may be a critical factor in quantifying the risk of skill deficits and technological unemployment. The methodology of Bardhan et al. [14] could be used to address this for European nations.

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