

‘Manufacturing a Stronger Economy for Wales and the UK’

Technology and the Productivity Challenge?



Literature Review

Jason Murphy

September 23

Table of Contents

1. Summary	3
2. Introduction	4
2.1 The Importance of Productivity	4
2.2 A Welsh Perspective	5
2.3 A UK Perspective	7
2.4 A Global Perspective	8
3. Views of Leading Economists	10
4. Technology Adoption – International Comparisons	12
5. Advanced Manufacturing Technologies	15
5.1 IIoT, MES and ERP	15
5.2 Automation & Robot Technology	17
5.3 Discrete Event Simulation	18
5.4 Digital Twins	19
5.6 Artificial Intelligence (AI) and Machine Learning (ML)	20
5.7 Blockchain	21
5.8 Cyber Security	22
6. The Social Perspective.....	23
6.1 Public Perception and Jobs	23
6.2 High Value Manufacturing and Skills	24
7. Conclusion.....	25
References	26

1. Summary

This literature review looks at the manufacturing sector and its contribution to the Welsh economy and UK economy. The sector contributes 17% to total industry Gross Value Added (GVA) in Wales but only 10% for the UK. The performance of the UK manufacturing sector in comparison with other countries (where manufacturing also makes an important contribution to the national economy) is also investigated. Particularly, attention is given to the weak productivity growth across all industries in the UK post the economic crash of 2007/8. The views of leading economists are researched to understand why the UK's performance in manufacturing has been noticeably poorer than that of its international peers' post 2007/8. The consensus amongst these economists is that the UK manufacturing sector is losing its competitiveness due to a lack of investment in technology. The areas of advanced manufacturing technology in which other countries are investing are explored, to understand where specifically the UK is lagging. An overview of the different advanced manufacturing technologies is also provided. It is the intention to use this literature review to support a larger piece of work that looks at the Welsh manufacturing sector in detail and assesses how different advanced manufacturing processes can be adopted to grow GVA and improve productivity.

2. Introduction

2.1 The Importance of Productivity

Productivity is widely acknowledged to influence living standards (McKinsey Global Institute, 2018) (Diewert, 2015) – higher productivity leads to higher wages and better health for the population, including a reduction in child mortality (see Figure 1). Productivity growth also influences the rate of inflation for which monetary policy is determined i.e., interest rates require adjustment to stimulate (or suppress) demand (Goodridge, 2016).

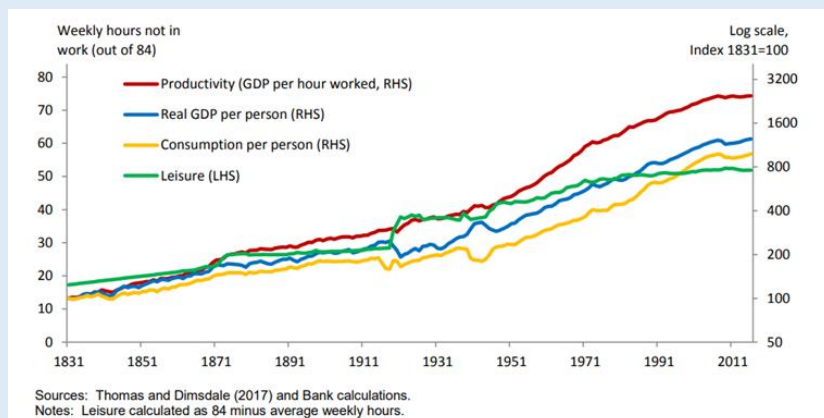


Figure 1 – Welfare relationship to productivity (Tenreyro, 2018)

Productivity is calculated by dividing the Gross Domestic Product (GDP) or Gross Value Added (GVA) of a country by either the population of the country or the number of hours worked (The Productivity Institute, 2022).

GVA is calculated as the monetary sum of all that has been produced in each period minus the cost of the associated intermediate inputs (raw materials, utilities etc.).

GDP is like GVA, but with the addition of government taxes and subtraction of government subsidies.

2.2 A Welsh Perspective

The manufacturing sector makes an important contribution to the Welsh economy. In 2021, the sector contributed £12bn (17%) to the Welsh total Gross Value Added (GVA) of £70bn (Welsh_Government, 2023). The sector employed 155,000 people in 2018 – which in terms of jobs as a percentage of jobs across all sectors, put Wales very close to the top of the league table for all UK regions (see Figure 2).

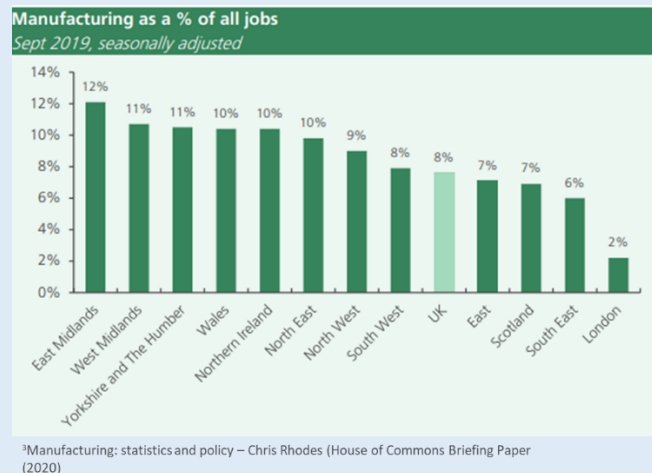


Figure 2 – Manufacturing as a % of all jobs

The Welsh Government publish economic indicators on a web based interactive dashboard. The output indicator looks at GVA per head and GVA per hour worked. In 2021 (the latest available results), productivity (GVA per hr) was the lowest of all UK regions (Welsh_Gov, 2023).

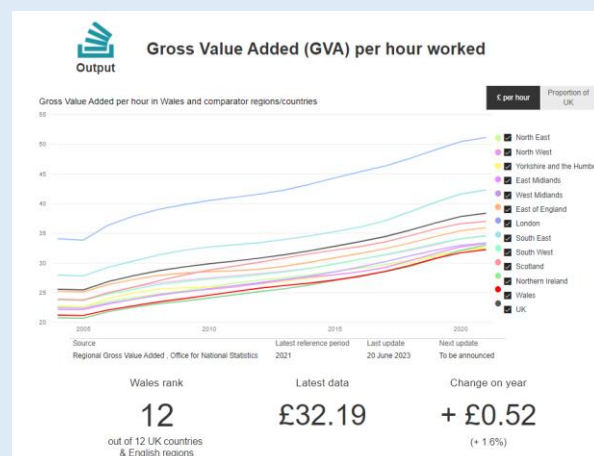


Figure 3 – GVA per hour worked all sectors (UK) – 2021 (Welsh_Gov, 2023)

Sector specific data is not calculated for GVA per hour worked, however it is available for GVA per job and in 2018, productivity (GVA/job) was 10% above the UK average in East Wales and 8% below the UK average in West Wales (see Figure 4) (Beatty & Fothergill, 2020).

Table 4: Manufacturing productivity by sub-region, 2018

	GVA per job UK=100	Employment
Cheshire & Warrington	241	41,500
Hertfordshire	157	34,500
Thames Valley Berkshire	151	25,500
Highlands & Islands	148	14,500
Coast to Capital	146	42,500
Swindon & Wiltshire	145	29,500
Oxfordshire	139	26,500
Coventry & Warwickshire	134	55,500
Enterprise M3	129	44,000
Greater Birmingham & Solihull	121	92,000
Liverpool City Region	120	49,000
North Eastern Scotland	116	22,500
East Wales	110	63,000
Eastern Scotland	110	62,500
Greater Cambridge and Greater Peterborough	104	85,000
South East	102	107,500
The Marches	101	38,500
South East Midlands	101	92,500
Lancashire	99	87,500
Northern Ireland	99	86,000
West of England	98	36,000
West Central Scotland	97	47,000
London	96	114,500
North East	95	90,500
Humber	95	68,500
New Anglia	94	66,500
West Wales & the Valleys	93	82,500
Leicester & Leicestershire	92	59,500
Southern Scotland	91	34,500
Greater Manchester	91	104,500
Cumbria	90	37,500
Gloucestershire	90	34,500
York, N Yorkshire and E Riding	86	56,000
Dorset	86	29,000
Tees Valley	84	25,000
Greater Lincolnshire	83	67,000
Buckinghamshire Thames Valley	83	17,500
Derby, Derbyshire, Nottingham, Notts	82	126,500
Leeds City Region	80	150,000
Worcestershire	77	34,000
Heart of the South West	76	70,500
Cornwall & Isles of Scilly	76	15,500
Stoke & Staffordshire	71	63,000
Solent	69	45,000
Sheffield City Region	67	92,500
Black Country	51	65,500
All manufacturing	100	2,520,000

Figure 4 – GVA per job (UK Regions) (Beatty & Fothergill, 2020)

The manufacturing sector of Wales appears to have a productivity level that broadly aligns with the UK average.

2.3 A UK Perspective

The manufacturing sector contributed £200bn (10%) to the UK total Gross Value Added (GVA) of £2000bn (Welsh_Government, 2023).

Since 2008, Real Value Added / hour worked has slowed considerably in the UK (Coyle & Mei, 2023) - see Figure 5. The UK entered the financial collapse of 2007/8 with a historically low level of productivity (McKinsey Global Institute, 2018). In the decade that followed, the UK economy experienced its worst period of average annual productivity growth (0.3%) since the 1800's. A fact so noteworthy that the Royal Statistical Society made it a 'statistic of the decade' (RSS, 2019). If the manufacturing sector performed any better, it was marginal (Figure 6).

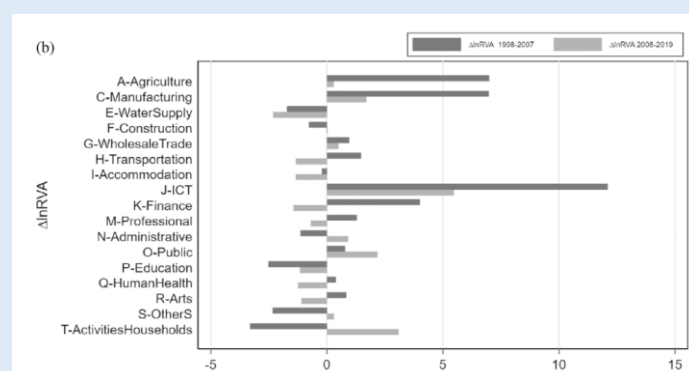


Figure 5 – Real Value Added per Hour worked for different sectors (1998-2007 and 2007 – 2019) (Coyle & Mei, 2023)

By 2019, total manufacturing output had failed to recover to pre-financial crisis levels (Figure 7) (Rhodes, 2020).

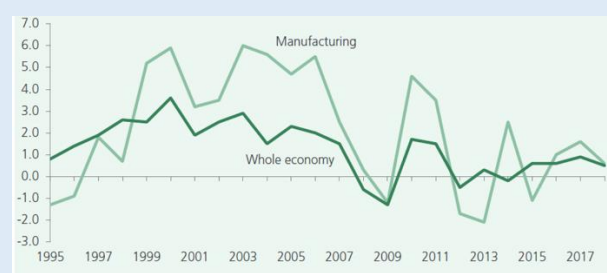


Figure 6 – UK Productivity Growth (Annual % Change) – Output/hr worked (Rhodes, 2020)

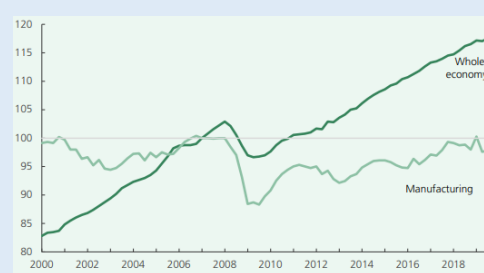


Figure 7 – Economic Output, GVA (Rhodes, 2020)

Indeed, the slowdown in UK productivity growth since 2007/8 has been attributed largely to the performance of both the manufacturing sector and the financial sector (see Figure 8).

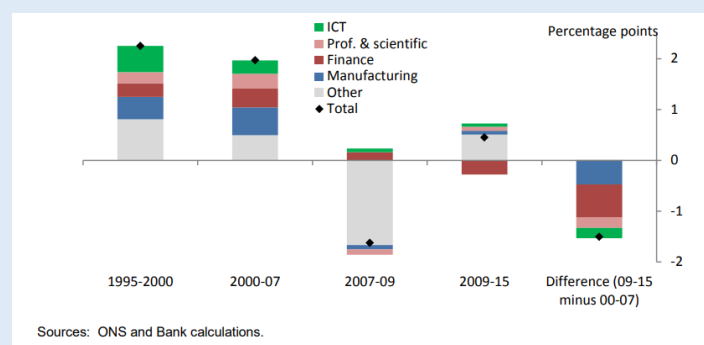


Figure 8 – Industry contributions to average annual UK labour productivity growth (Oulton, 2016)

2.4 A Global Perspective

In 1970, the UK ranked in the top 20 (across 237 countries) for each of the 3 manufacturing output measures shown in Figure 9. By 2015 the standings had changed dramatically. Indeed, the UK ranked a lowly 118th for 'manufacturing output as a % of Gross Domestic Product' (Rhodes, 2018). In 2020, the UK ranked 10th in the global league for value added by the manufacturing sector to GDP (see Figure 10).

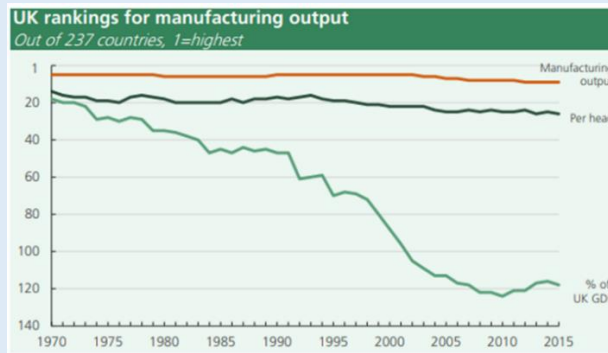


Figure 9 – UK Ranking for Manufacturing Output (Rhodes, 2018)

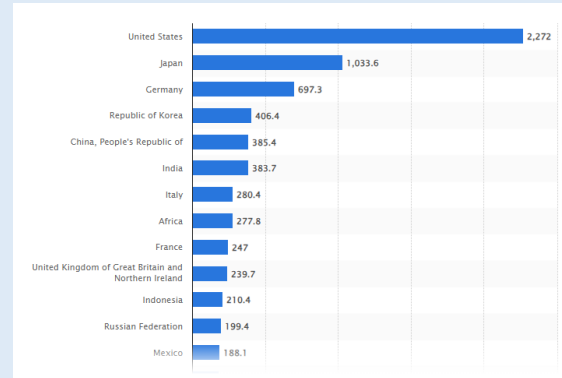


Figure 10 – Manufacturing sector GDP (University, 2023)

For almost two centuries, the UK has transitioned from a manufacturing nation to one that is services led (UK_Gov, 2015). In the 1960's, there was a sharp acceleration of that transition (see Figure 11). Between 1998 and 2017, significantly more UK manufacturing jobs disappeared than in Italy, France, Germany, and the United States (see Figure 12).

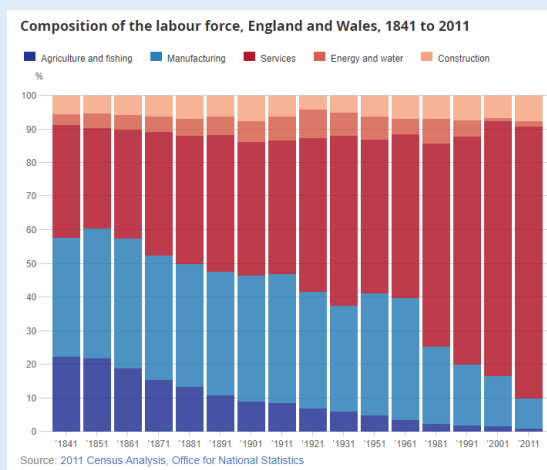


Figure 11 – Labour force composition – England and Wales (UK_Gov, 2015)

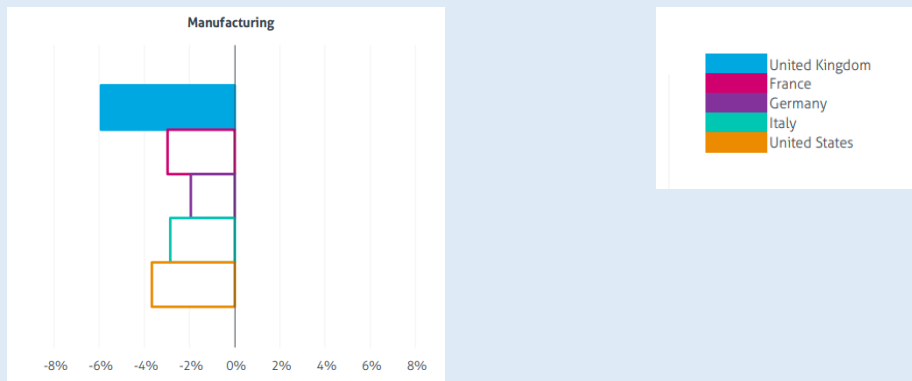


Figure 12 – UK Manufacturing Growth in Employment 1998-2017 (Economic Policy Institute, 2000)

The apparent demise of the UK manufacturing sector over recent decades is disappointing. However, a cause for greater concern is that between 1998 and 2015, the UK manufacturing sector contributed more to the overall slowdown of the economy than in many competing nations (Coyle & Mei, 2023) (see Figure 13).

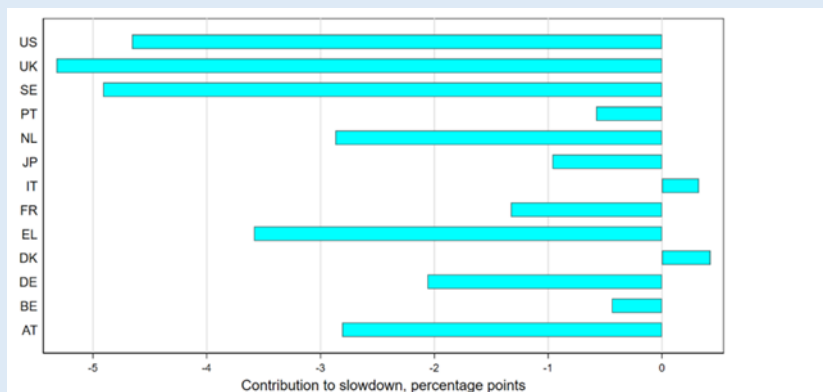


Figure 13 – Contribution of slowdown from manufacturing sector across countries (Coyle & Mei, 2023)

3. Views of Leading Economists

1. The movement towards a service-based economy was not unique to the UK, indeed this happened across much of the developed world. Yet, there was one significant difference - although manufacturing as a % GDP fell significantly across all these nations when calculated using current prices, the same was not true when using constant prices (Chang, 2014):
 - In the USA, Finland, Sweden, Switzerland – manufacturing as a % GDP increased.
 - In Germany, France, and Italy – manufacturing as a % GDP fell by < 10%.
 - Whereas, in the UK – manufacturing as a % GDP fell dramatically.

This was a strong indicator that the UK had become uncompetitive relative to many of its peers.

2. In a speech to the Bank of England in 2018, Professor Silvana Tenreyro evidenced that weak capital investment was responsible for a third (see Figure 14) of the reduced productivity growth in manufacturing when comparing the pre-crash period of 2000-07 against the post-crash period of 2009-15 (Tenreyro, 2018).

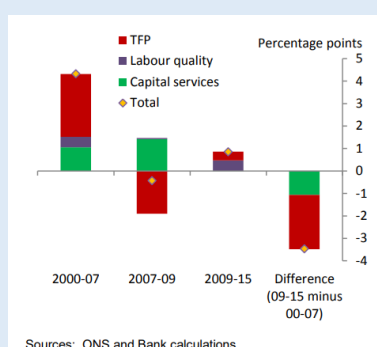


Figure 14 – Contributions to UK manufacturing average annual productivity growth 2009-2015 (Tenreyro, 2018)

Professor Tenreyro gave a compelling argument that the balance of reduced productivity growth was due to onshoring – evidenced by a reduced relative price of manufactured goods and a reduction in hours worked during the period 2000-07 when productivity growth was strong (Tenreyro, 2018).

3. Between 2010-15, investment in fixed capital by the UK manufacturing sector fell more than Spain, France, Germany, and the United States (see Figure 15).

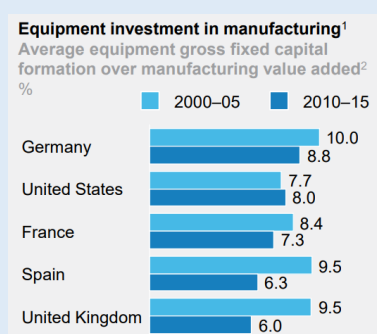


Figure 15 – Average equipment GFCF over manufacturing GVA % (McKinsey Global Institute, 2018)

GFCF is one of a few undisputed indicators of an economies cap ability to grow (Chang, 2014).

4. The reluctance of the UK manufacturing sector to invest in new capital since 2009, was attributed mainly to the abundance of cheap labour available. Businesses chose cheap labour over capital investments and as a result, unemployment hit a 30-year low (The Productivity Institute, 2022) (Baily, Bosworth, & Siddhi, 2020). It is a concern is that the UK's reticence to invest in capital equipment is not mirrored by the rest of the world – particularly the emerging market economies (see Figure 16).

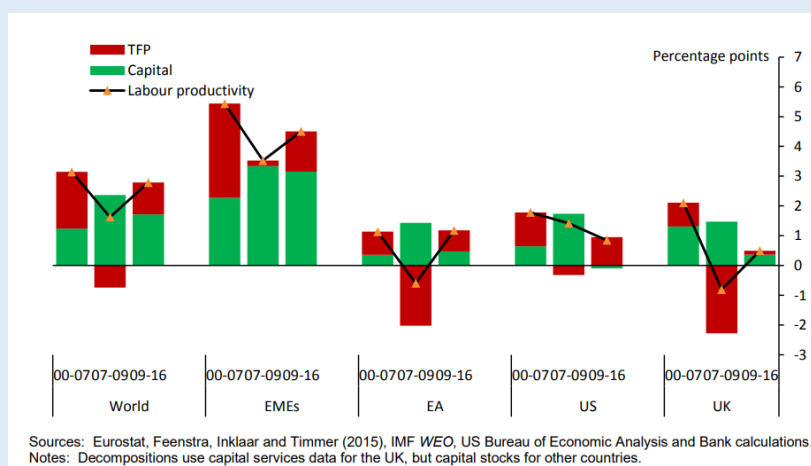


Figure 16 – Contributions to productivity growth across different economic regions (Tenreyro, 2018).

5. The capability of an economy to grow is governed primarily by a countries ability to keep transforming its production activities (Chang, 2014).

4. Technology Adoption – International Comparisons

The countries that are contributing the most to global manufacturing output, China 20%, USA 18%, Japan 10%, Germany 7% and Rep of Korea 4% (Rhodes, 2018) are investing in industrial robots (**Error! Reference source not found.**). The UK did not make the ‘Top 15’ in the ‘international league table’ for annual installations of Robots (Figure 17) (International Federation of Robotics, 2021).

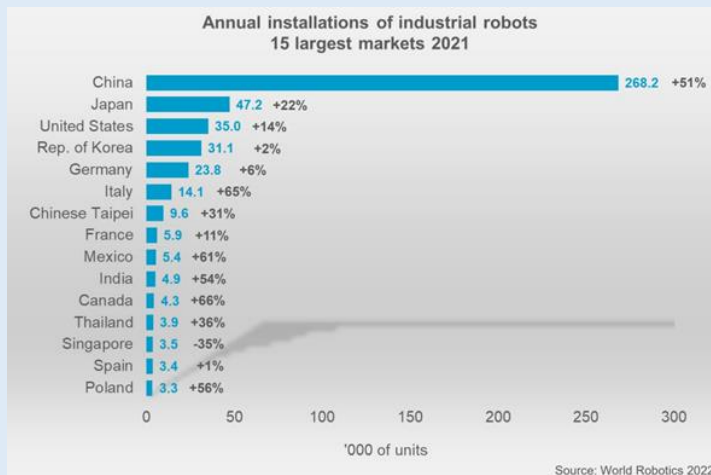


Figure 17 – Global Installations (International Federation of Robotics, 2021)

The UK trails some of its peers in the use of Enterprise Resource Planning (ERP) software and the use of Supply Chain Management software (Figure 18). Furthermore, the UK is behind the rest of the world in adopting next generation technologies such as ‘Internet of Things’, Advanced Artificial Intelligence, Converged Infrastructure, High Performance Computing and Virtual/Augmented reality (McKinsey Global Institute, 2018).

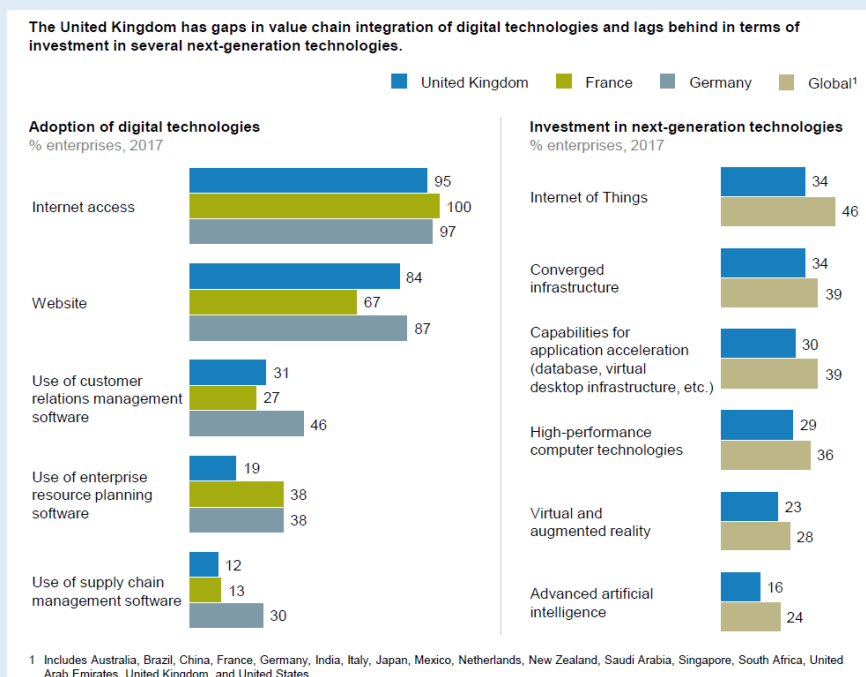


Figure 18 – Value Chain Integration of Digital Tech & Investment in next Generation Tech (McKinsey Global Institute, 2018)

The United Nations Industrial Development Organisation (UNIDO) assess and score the competitiveness of different nations using three dimensions (UNIDO, 2021) – see Figure 19.



Figure 19 – UNIDI Competitive Industrial Performance Dimensions (UNIDO, 2021)

1. Dimension 1 focuses on the capacity to produce and export manufactured goods:
 - a. Manufacturing value added per capita, and,
 - b. Manufactured exports per capita
2. Dimension 2 looks at the technological deepening and upgrading through:
 - a. Industrialisation Intensity – assessing the complexity of the manufacturing process, and,
 - b. Export Quality – looking at the technological complexity and total volume of exported manufactured goods as a percentage of total exports.
3. Dimension 3 considers the world impact:
 - a. Manufacturing value added as a percentage of total global manufacturing value added.
 - b. Share in global trade of manufactured goods.

In 2018, the UK ranked 15th overall (a drop of 1 place since 2017) – see Figure 20.

Quintile	Rank 2018	Economy	Score	Rank 2017	Rank 2012	Change 2017-2018	Change 2012-2018
Top	1	Germany	0,4709	1	1	0 ↔	0 ↔
Top	2	China	0,3716	2	5	0 ↔	3 ↑
Top	3	Republic of Korea	0,3488	3	4	0 ↔	1 ↑
Top	4	United States of America	0,3454	4	2	0 ↔	-2 ↓
Top	5	Japan	0,3445	5	3	0 ↔	-2 ↓
Top	6	Ireland	0,3304	6	13	0 ↔	7 ↑
Top	7	Switzerland	0,302	7	6	0 ↔	-1 ↓
Top	8	China, Taiwan Province	0,2841	8	8	0 ↔	0 ↔
Top	9	Singapore	0,2591	9	7	0 ↔	-2 ↓
Top	10	Netherlands	0,252	10	9	0 ↔	-1 ↓
Top	11	Italy	0,2443	11	11	0 ↔	0 ↔
Top	12	Belgium	0,2419	12	12	0 ↔	0 ↔
Top	13	France	0,2371	13	10	0 ↔	-3 ↓
Top	14	Austria	0,2051	15	16	1 ↑	2 ↑
Top	15	United Kingdom	0,2049	14	14	-1 ↓	-1 ↓
Top	16	Czechia	0,2019	16	18	0 ↔	2 ↑
Top	17	Sweden	0,1953	17	15	0 ↔	-2 ↓
Top	18	Spain	0,1811	19	19	1 ↑	1 ↑
Top	19	Canada	0,1792	18	17	-1 ↓	-2 ↓
Top	20	Mexico	0,1644	20	20	0 ↔	0 ↔

Industrialized economies

Emerging industrial economies

Figure 20 – Global Competitive Industrial Performance Index – 2018 (UNIDO, 2021)

However, when looking at the ranking for the UK against each dimension, there are deeper concerns for the UK manufacturing sector. In particular, the UK ranks 35th for technological deepening and upgrading, which is not a surprise considering the lack of capital investment that was discussed earlier.

Regional rank	Economy	Global rank	Rank in the first dimension	Rank in the second dimension	Rank in the third dimension	Absolute change compared to 2012
1	Germany	1	5	6	3	0 ↔
2	Ireland	6	1	3	23	7 ↑
3	Switzerland	7	2	11	16	-1 ↓
4	Netherlands	10	6	28	13	-1 ↓
5	Italy	11	18	21	6	0 ↔
6	Belgium	12	4	24	19	0 ↔
7	France	13	21	22	7	-3 ↓
8	Austria	14	7	18	26	2 ↑
9	United Kingdom	15	29	35	9	-1 ↓

Figure 21 – Europe Competitive Industrial Performance Index - 2018 (UNIDO, 2021)

5. Advanced Manufacturing Technologies

It is the recent acceleration in the available power of computing technology (including the advancement in silicon GPU's and CPU's, hyperscale infrastructures and cloud computing) that has enabled the storage, processing, interpretation, and manipulation of incredibly large volumes of data to generate insights and use AI algorithms to make automatic highly intelligent decisions.

The factories of the future will involve highly complex and customised models that require the integration and alignment of the entire supply chain for dynamic manufacturing (Frank, 2019). This introduces technical challenges that might be obvious such as scale, complexity, and security. However, it also introduces many new softer challenges such as the levels of acceptable transparency to each stakeholder, accountability for data accuracy and IP rights (Castelo-Branco, 2019).

Some of these softer barriers can be broken through the adoption of blockchain technology and the Web of Things (WoT) to ensure data consistency across different supply chain platforms and protecting partner IP (Li, 2018). This would help to streamline the flow of goods, records and receipts, tracking, financial transactions and possibly knowledge transfer across the whole value chain (Saqlain, 2019).

5.1 IIoT, MES and ERP

Industry 4.0 is bringing a new wave of automation in which connected systems and machines outperform cognitive and physical human capabilities and unconnected systems.

The 'Industry 4.0' journey for manufacturing businesses and their supply chains starts with the identification of the right IIoT (Industrial Internet of Things) devices. This is the starting point for the vertical integration of all equipment and systems incorporated within all the manufacturing processes and management systems. It is also the starting point for involving the people who will interact with them (Gilchrist, 2016). At the basic entry level for manufacturing businesses, this involves connecting IIoT sensors to automation and standalone machinery, which in-turn feed wireless gateways (see Figure 22) that can be connected through the cloud to a simple dashboard (see Figure 23) for data insights. Indeed, some IIoT sensors can connect directly to the cloud without a gateway device.



Figure 22 – Typical IIoT Sensors and Gateways (Frank, 2019)

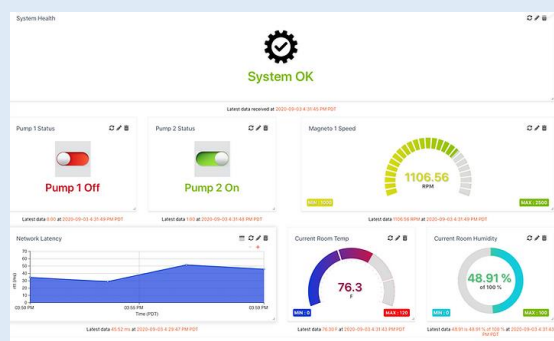


Figure 23 – Typical basic Dashboard (Frank, 2019)

The most frequently used communication protocols for IIoT are OPC-UA and Message Queuing Telemetry Transport (MQTT). Manufacturing and process data collected via Distributed Control

Systems (DCS), Programmable Logic Controllers (PLC) and Supervisory Control & Data Acquisition (SCADA) can be harnessed under an overarching Manufacturing Execution System (MES) that has 11 core functions such as Quality Management, Resource Allocation, Product Tracking, Process Management etc. (see Figure 24) (Ghobakhloo, 2018).

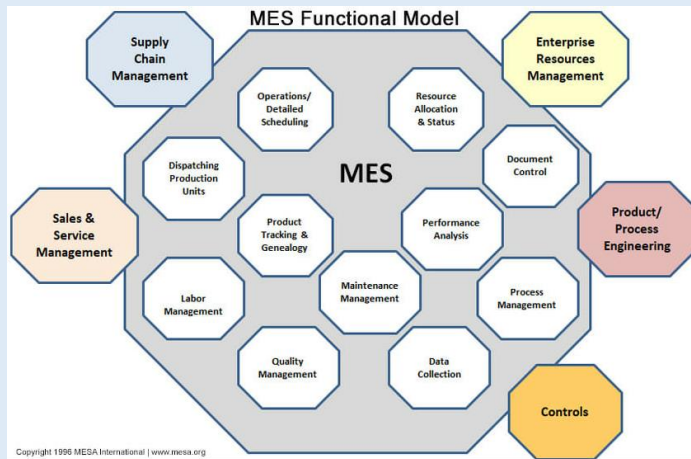


Figure 24 – The 11 core functions of a MES system (Ghobakhloo, 2018)

A layer above the MES system, at the top of the hierarchy of connectivity, sits the Enterprise Resource Planning (ERP) system (see Figure 25).

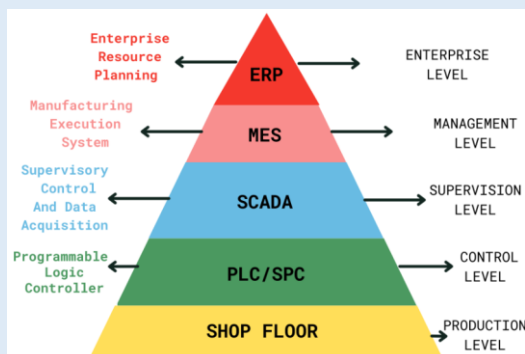


Figure 25 – Hierarchy of Connectivity (Ghobakhloo, 2018)

ERP creates the comprehensive information system that integrates all elements of the business.

5.2 Automation & Robot Technology

The manufacturing sector has one of the highest potentials for automation across all sectors. A recent study by the McKinsey Institute estimated the automation potential for manufacturing to be 60% (McKinsey&Company, 2017) - see Figure 26.

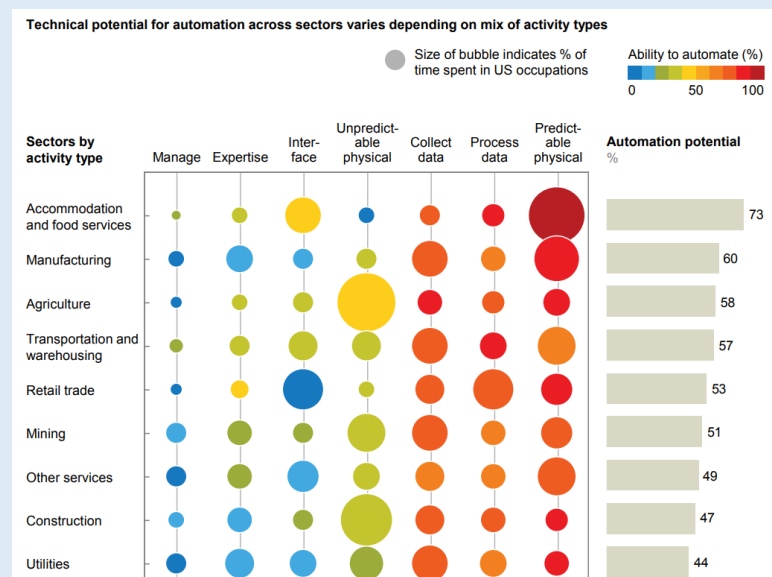


Figure 26 – Technical potential for automation across sectors (McKinsey&Company, 2017)

The greatest potentials for automation within manufacturing are in the areas of data collection, processing data and predictable physical activities – some examples of the automation of predictable physical activities within the food and drink sector (installed by EBS Automation – a Welsh System Integrator) are shown in Figure 27.

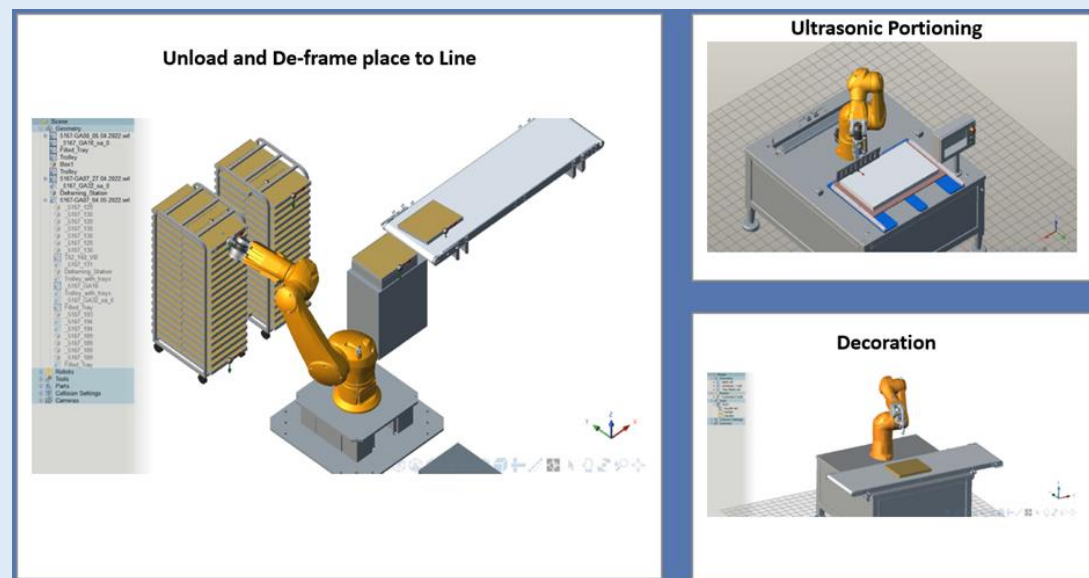


Figure 27 – Robot Cell Food & Drink – EBS Automation

Scenario modelling by the McKinsey Institute estimates that automation could boost global productivity by up to 1.4% annually.

5.3 Discrete Event Simulation

Discrete Event Simulation software has been used for decades to create a digital model of manufacturing lines to identify bottlenecks by simulating the flow of product through the different machinery and internal logistics (see Figure 28). Capacity of the line can be optimised through an iterative process of identifying the bottleneck, redesigning the layout to break the constraint, then re-running the simulation to identify the new improved line capacity and the new bottleneck. The whole cycle can then be repeated.



Figure 28 – Siemens Discrete Event Simulation Software (Plant Sim)

With the recent explosion of IIoT devices, there is now an exciting potential for DES models to become cyber twins of the physical lines. Real time data from the IIoT devices on machinery can be fed to the DES model for the execution of queries that support better planning, management and decision making.

Work to create Digital Twins from DES models is in its infancy, but when coupled with AI and ML, the opportunities for improving business performance are significant. This is an important area for technology development (McKinsey&Company, 2017).

5.4 Digital Twins

There are many providers of platforms for creating Digital Twins (see Table 1).

Company	Platform	Scale	Function	Application
GE	Predix	1 million digital twins and hundreds of industrial apps	Secure monitoring of linked assets, industrial data management and analysis, cloud technology applications and mobility	Aviation, power, medical, energy, transportation, finance, etc.
Siemens	MindSphere	Interconnection of approximately 1 million devices and systems	Predictive maintenance, energy data management, resource optimization, etc.	Industry, manufacturing and other fields
PTC	ThingWorx	21 enterprise applications, 142 plugins, 77 certified products	Modernized rapid application development tools and service operations capabilities for application developers or industrial SaaS operators	Manufacturing
ABB	Ability	More than 70 million connected devices and 70,000 control systems	Remote monitoring services for robotics, motors and machinery; control solutions for building, offshore and electric vehicle charging infrastructure; and professional solutions for energy management and ocean fleet routing optimization	Power automation, transportation, data centers, smart buildings, mining, petrochemicals, and manufacturing enterprises
Schneider	EcoStruxure	More than 45,000 systems with 9000 system integrators	Interconnection of power systems and equipment, data acquisition and analysis of equipment and optimization of industrial performance	Building, information technology, factories, power distribution, power grids and machines
Phoenix Contact	ProfiCloud	/	Device access and interconnection, as well as data collection and analysis	Wind power, photovoltaic power generation, oil and gas, water conservancy facilities and manufacturing enterprises
Emerson	PlantWeb	/	Equipment and energy analysis, equipment management, remote support services	Process industry
CASlCloud	INDICS	More than 500 kinds of self-developed software and public research application APP	Intelligent R&D, lean manufacturing, intelligent services, smart enterprises, ecological applications, and other industrial application capabilities of product life cycle	Aerospace, high-end equipment manufacturing, automotive, and mold manufacturing
Shugen Interconnect	Rootcloud	More than 400,000 high-value equipment	Operation monitoring, fault diagnosis, statistical analysis, equipment control, maintenance management, spare parts forecasting, etc.	Energy, textiles, special vehicles, port machinery, agricultural machinery and construction machinery, etc.
Haier	COSMOplat	28 application scenarios and 179 solutions	Product design, manufacturing, logistics and distribution, iterative upgrades, etc.	Building ceramics, agriculture, motor homes, molds, machinery, etc.
Zoomlion	ZValley OS	More than 200,000 sets of equipment, more than 9000 kinds of data parameters	Device connection, big data analysis, micro service application APP, etc.	Industrial Interconnect, Smart City, Smart Agriculture and Industrial Finance

Table 1 – Other industrial internet platforms (source (Tao, 2022))

The Siemens Mindsphere platform is particularly interesting for manufacturing, because of its ‘factory twin’ application. An overview of the Mindsphere system architecture is shown in Figure 29, with delineation between the cyber world and the physical world clearly shown.

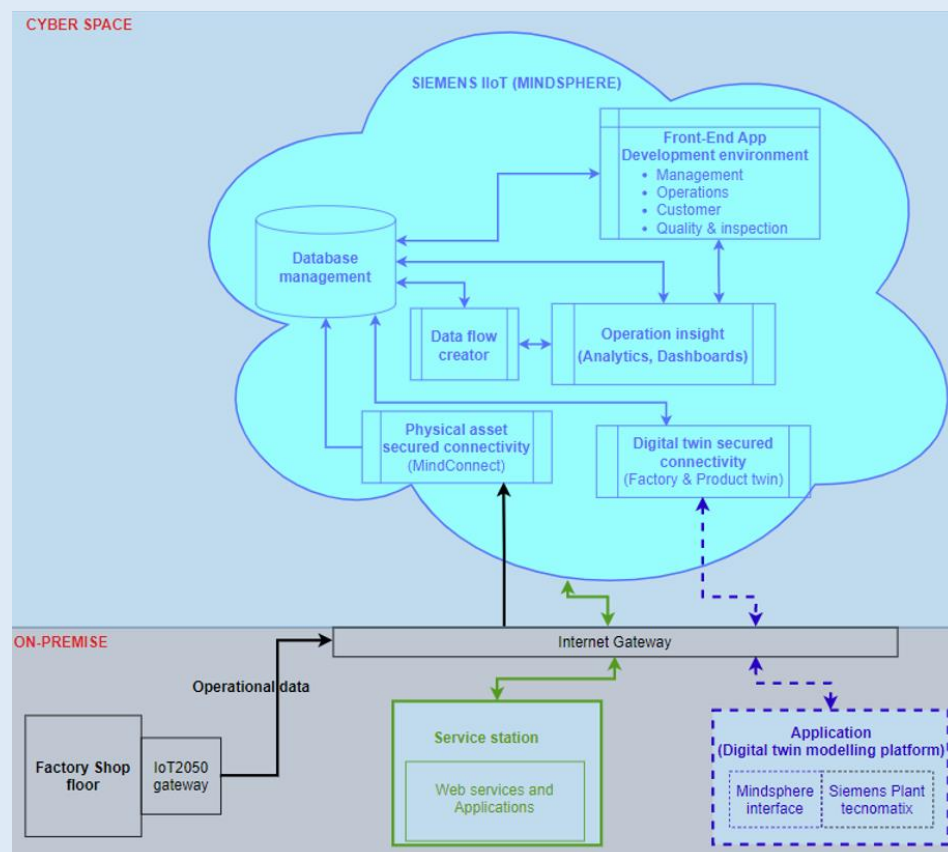


Figure 29 – Mindsphere System Architecture (Siemens, 2023)

Factory Twin is an application in Mindsphere that connects the DES virtual model to the IIoT Physical Assets in the factory by mapping them together. This creates a 'true' Digital Twin, allowing production replays of real shop floor process activity. It also permits the modelling of 'what-if' scenarios to optimise future production runs.

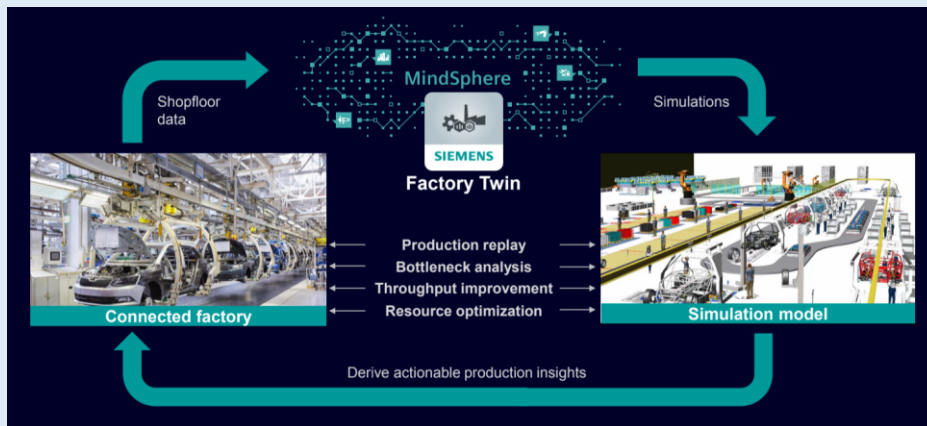


Figure 30 – Factory Twin (Siemens, 2023)

5.6 Artificial Intelligence (AI) and Machine Learning (ML)

Artificial Intelligence and Machine Learning has come a long way since the first algorithms were developed by Christopher Strachey at Oxford University in 1951 that performed reasonably well in the board game of Draughts. There has been an explosion of interest in this field during the last decade, mainly due to the advancements in high performance computing and cloud computing that has enabled the processing of intensive data activities.

AI and ML have many potential applications across different sectors. Within the manufacturing sector, these include Optimising scheduling in real time, predictive maintenance, automatic identification of defective parts etc (see Figure 31).

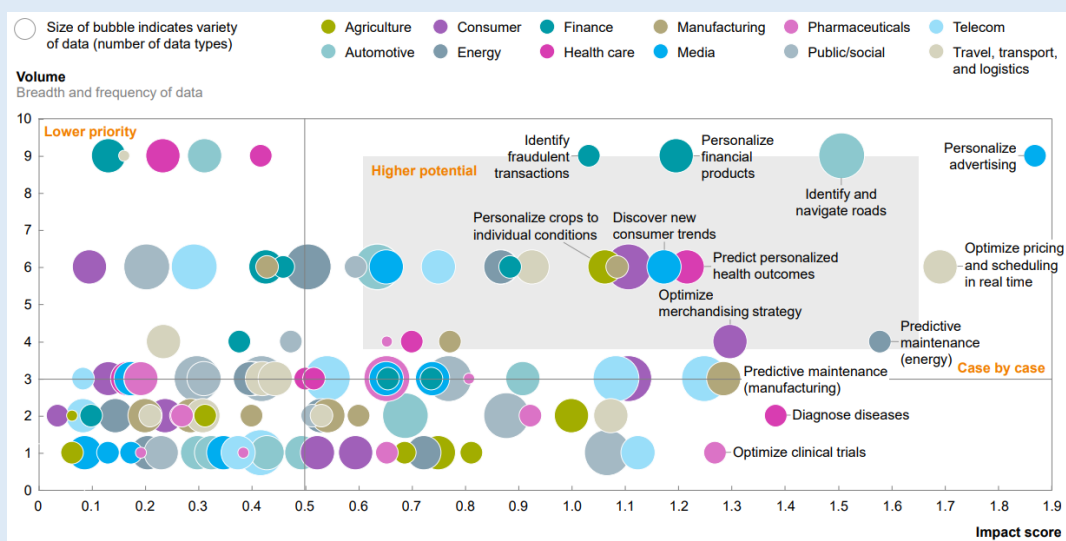


Figure 31 – The Potential for Machine Learning Across Industries and Use Cases (source - (McKinsey Global Institute, 2018))

For the 'Food' sector, AI has an important role to play in food security and food quality, through image processing and mathematical modelling (see Figure 32).

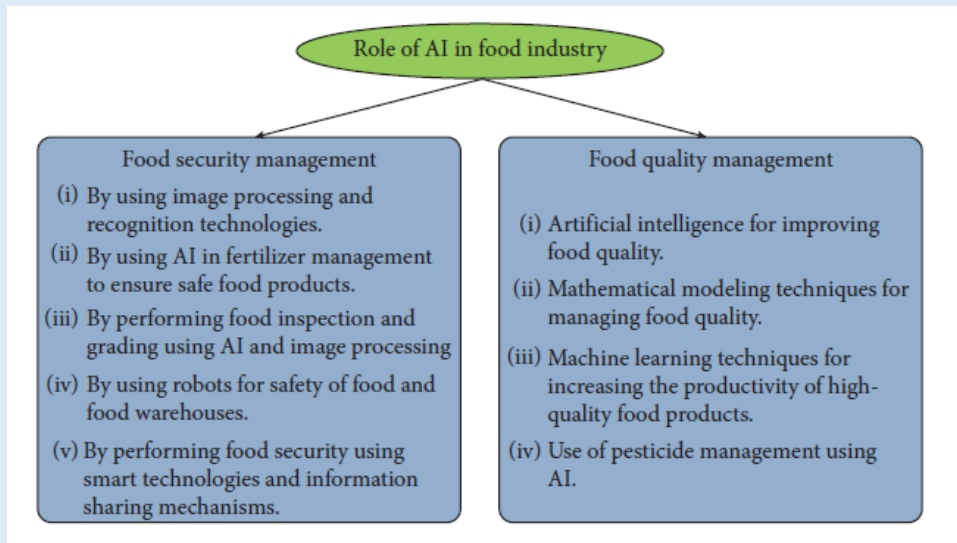


Figure 32 – AI in the Food - (Kumar, 2021)

5.7 Blockchain

Blockchain facilitates transparency across businesses and their supply chains in a network where traditionally, collaboration is not strong because of a lack of trust. Blockchain is the dawn of the 'smart contract' era, eradicating paper contracts and transactions. Blockchain provides data attribution through a robust mechanism of audit trail.

Blockchain is little more than a very intelligent database. It is a type of distributed ledger technology, providing a single source of truth for transactions (Tao, 2022). The ledgers are decentralised in terms of geography (with nodes located in different countries) and governance (where no single organisation has control of the network). Blockchain is a data structure that contains blocks (containing transactions, timestamps, and digital signatures) that are linked together by cryptographic hashes (see Figure 33). The integrity is provided through the hash linkages i.e., tampering with Block#1 would mean that the hashes in Block#0 and Block#1 no longer align.

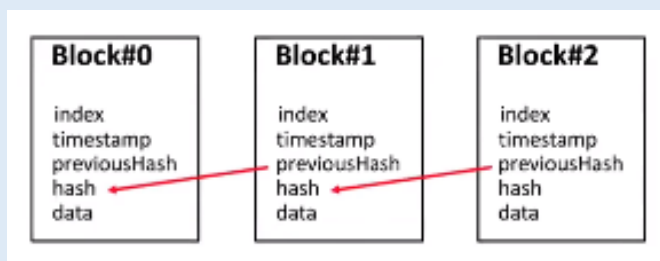


Figure 33 – Blocks and Hashes (Tao, 2022)

This has significant implications for manufacturing. There is excitement about the development work taking place to use Blockchain with Digital Twin technology to ensure the reliability of data that is transferred between physical and cyber assets.

5.8 Cyber Security

IEC 62443 is a series of international standards that provides guidance on Cybersecurity with respect to automation and control systems. This series describes the minimum levels of security that the manufacturing sector should provide within their operational systems and processes. Recommendations for the protection of networks against internal and external intrusions include:

- The segmentation of production lines to create individual secure cells.
- VPN protection – a certification to allow remote access to the network.
- Zero Trust – Users must be identified and authorised before timebound access.
- Firewall and network management.

6. The Social Perspective

6.1 Public Perception and Jobs

The link between productivity and living standards is well documented. Countries with high levels of productivity have higher levels of Gross Domestic Product and higher value goods and services. These productive countries also pay higher wages, and they have better healthcare, housing, food, holidays etc... (Economic Policy Institute, 2000).

There is, however, a mistrust of technology by much of the public. It is born from a fear that technology will take jobs from people. The reality is that only 5% of occupations can be fully automated, whilst 60% of occupations could have 30% of tasks automated by currently demonstrated technologies (see Figure 34). Therefore, the real challenge that businesses face, is to identify the most efficient and safe ways for humans and technology to work together.

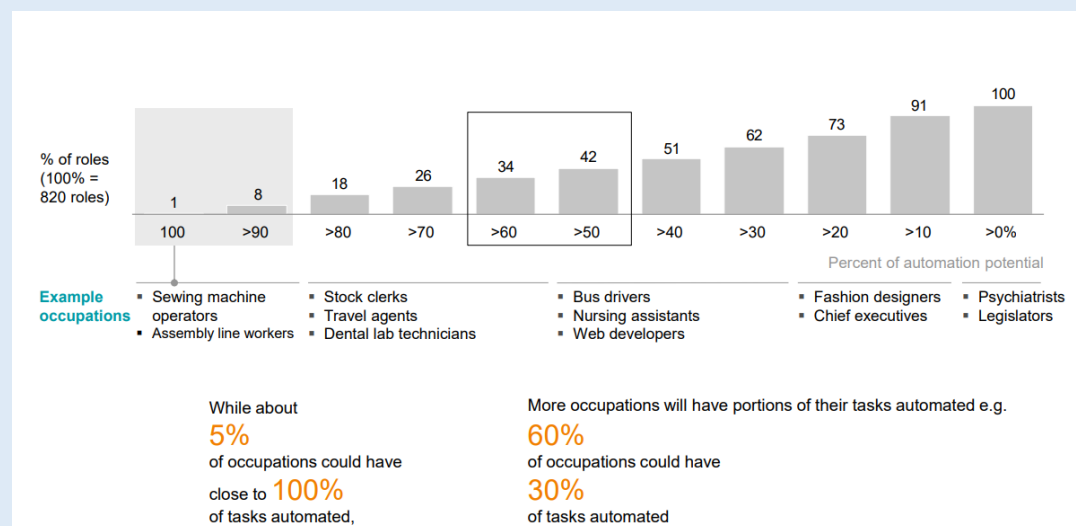


Figure 34 – Examples of Occupations and the levels to which they can be Automated (Manyika, 2017)

6.2 High Value Manufacturing and Skills

To define High Value Manufacturing, the Cambridge University Institute for Manufacturing developed the following matrix of metrics for each stakeholder and type of value (see Figure 35).

	Financial	Strategic	Social
Country	• GDP impact payed	• Sustainable employment • Intellectual capital development • Employee capability development	• Minimal environmental impact
Investors	• Return adjusted for risk • Long term growth	• Adaptability, sustainability	• Acts ethically
Employees	• Pay, wages • Funding of retirement	• Lifelong learning • Opportunities for growth	• Personal development • Social interaction • Work-life balance

Figure 35: Matrix of HVM metrics for each stakeholder (source (Livesey, 2006))

The challenge facing all UK manufacturing stakeholders is to move business up the value chain and make high value the standard. The key to this is securing the benefits of high-skilled, knowledge-intensive manufacturing operations whilst competing on unique value and innovation (Livesey, 2006).

7. Conclusion

The productivity of both the Welsh and UK manufacturing sector is lagging international peers. It is extremely concerning that the UK lags these peers and other countries from emerging economies who are making significant investment in advanced manufacturing technologies. The Welsh economy is more sensitive to the performance of the manufacturing sector since its percentage contribution to total sector GVA is almost twice that for the UK. If the status quo remains, the Welsh manufacturing sector (and indeed the UK manufacturing sector) will become increasingly uncompetitive – putting pressure of jobs, communities, and governments.

WORD COUNT - 4032

References

- Baily, M., Bosworth, B., & Siddhi, D. (2020). *Productivity Comparisons: lessons from Japan, Germany, USA*. Washington: Brookings Institution.
- Beatty, C., & Fothergill, S. (2020). *The Productivity of Industries and places*. Sheffield: Sheffield Hallam university.
- BEIS. (2021). *UK Innovation Strategy 'Leading the future by creating it'*. London: UK GOV.
- Castelo-Branco, I. (2019). Assessing Industry 4.0 Readiness in Manufacturing: Evidence for the European. *Comput.Ind*, 22-32.
- Chang, H.-J. (2014). *Economics: The Users Guide*. London: Pelican.
- Climate Change. (2021, July 28). *What's the difference between 1.5 and 2 degrees of global warming*. Retrieved from World Economic Forum: <https://www.weforum.org/agenda/2021/07/2c-global-warming-difference-explained/>
- Coronado, P. D. (2018). *Part Data Integration in the Shop Floor Digital Twin: Mobile and Cloud*. Atlanta: Georgia Institute of Technology.
- Coyle, D., & Mei, J. C. (2023). *Diagnosing the UK productivity slowdown: which sectors matter and why*. Economica.
- Diewert, W. E. (2015). Decompositions of Productivity Growth into Sectoral Effects. *Productivity Analysis*, 367-387.
- Economic Policy Institute. (2000). *The Link Between Productivity Growth and Living Standards*. Washington: EPI.
- Frank, A. G. (2019). Industry 4.0 Technologies: Implementation Patterns in Manufacturing Companies. *Int.J.Prod.Econ*, 15-26.
- Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Manufacturing Technology Management*, 910-936.
- Gilchrist, A. (2016). *Industry 4.0*. New York: Apress.
- Goodridge. (2016). *Accounting for the UK productivity puzzle*. London: Economica.
- HM_Government. (2017). *Industrial Strategy 'Building a Britain fit for the future'*. London: UK GOV.
- Intergovernmental Panel on Climate Change. (2022). *Climate Change 2022 'Impacts, Adaption and Vulnerability*. IPCC.
- International Federation of Robotics. (2021, October 28). *World Robotics 2021*. Retrieved from IFR Downloads: https://ifr.org/downloads/press2018/2021_10_28_WR_PK_Presentation_long_version.pdf
- International_Federation_Robotics. (2018). *Robots and the Workplace of the Future*. Frankfurt: IFR.
- Kumar, A. (2021). Opportunities of Artificial Intelligence and Machine Learning in. *Journal of Food Quality*, 10.
- Li, Z. (2018). Toward a Blockchain Cloud Manufacturing System as a Peer to Peer Distributed Network. *Robot.Comput.Integr.Manuf*, 133-144.
- Livesey, F. (2006). *Defining High Value Manufacturing*. Cambridge: University of Cambridge IfM.
- Manyika, J. (2017, June 1). *A Future that Workes*. Retrieved from Resaerch, Insight, Impact: <https://www.jbs.cam.ac.uk/wp-content/uploads/2020/08/170622-slides-manyika.pdf>
- McKinsey Global Institute. (2018). *Solving the United Kingdom's Productivity Puzzle in a Digital Age*. London: McKinsey & Company.
- McKinsey&Company. (2017). *A Future that Works: Automation, Employment and Productivity*. San Francisco: McKinsey.

- NASA. (2023). *Earth Observatory*. Retrieved from NASA: <https://earthobservatory.nasa.gov/world-of-change/global-temperatures>
- Oulton, N. (2016). The Mystery of TFP. *Productivity Monitor*, 68-87.
- Rhodes, C. (2018). *Manufacturing: international comparisons*. London: House of Commons.
- Rhodes, C. (2020). *Manufacturing: Statistics & Policy*. London: House of Commons Library.
- RSS. (2019, December 19). *The Royal Statistical Society announces its*. Retrieved from Royal Statistical Society: https://rss.org.uk/RSS/media/File-library/News/Press%20release/RSS_Statistics_of_the_Decade.pdf
- Saqlain, M. (2019). Framework of an IoT-Based Industrial Data Management for Smart Manufacturing. *J.Sens.Actuator*, 25.
- Siemens. (2023). *Digital Twins*. Retrieved from Siemens: <https://www.plm.automation.siemens.com/global/en/our-story/glossary/digital-twin/24465>
- Sweis, D. (2022, August 24). *Demystifying Automation: Inspire Your Team To Embrace New Technology, Not Fear It*. Retrieved from Forbes: <https://www.forbes.com/sites/forbestechcouncil/2022/08/24/demystifying-automation-inspire-your-team-to-embrace-new-technology-not-fear-it/?sh=23238e3d4e9c>
- Tao, F. (2022). Digital twin and blockchain enhanced smart manufacturing service. *Journal of Manufacturing Systems*, 903-914.
- Tenreiro, S. (2018, January 15). *The fall in productivity growth*. Retrieved from Bank of England: <https://www.bankofengland.co.uk/-/media/boe/files/speech/2018/the-fall-in-productivity-growth-causes-and-implications>
- The Productivity Institute. (2022). *Productivity in the UK: Evidence Review*. London: National Institute of Economic and Social Research.
- UK Government. (2021). *Industrial Decarbonisation Strategy*. London: UK GOV.
- UK_Gov. (2015, August 6). *Transition from a manufacturing to service led labour market over past 170 years*. Retrieved from UK-Gov: <https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/articles/transitionfromamanufacturingtoserviceledlabourmarketoverpast170years/2015-08-06#:~:text=In%201841%20most%20people%20worked,industry%20and%2010%25%20in%20manufac>
- UNIDO. (2021). *Competitive Industrial Performance Report*. United Nations Industrial Development Organisation.
- University, S. (2023). *Value added to the manufacturing industry to GDP in 2020 by country*. Retrieved from Statista: <https://www.statista.com/statistics/456342/relative-comparison-of-value-added-in-manufacturing-of-leading-countries/>
- Welsh_Gov. (2023). *Welsh economy in numbers: interactive dashboard*. Retrieved from Welsh Government: <https://www.gov.wales/welsh-economy-numbers-interactive-dashboard>
- Welsh_Government. (2023, April 27). *Gross Value Added*. Retrieved from StatsWales: <https://statswales.gov.wales/Catalogue/Business-Economy-and-Labour-Market/Regional-Accounts/Gross-Value-Added-GDP/gvainwales-by-industry>



productivity