Life Sciences and Health in South West Wales: A sub-regional innovation ecosystem

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Abstract

South Wales has been nurturing a nascent Life Sciences cluster through initiatives including the Institute of Life Science (ILS) at Swansea University Medical School. ILS aims to provide an entrepreneurial learning environment transcending industry, healthcare, academia and further education. This chapter describes how efforts to develop the sector have been undertaken through structured efforts of *Understanding*, *Acting* and *Measuring*, resulting in new ventures formed through spin-outs to commercialise research output and collaboration with other enterprises. Building upon concepts of clustering and regional innovation systems, the approach demonstrates the harnessing of a long-term strategy involving *smart specialisation* resulting in emerging and meaningful economic impact. Networking and knowledge exchange are shown as core components of a system reaching across wider sectors involving a diversity of skills. The conclusions demonstrate how entrepreneurial learning has also helped develop further actions including *Talent Bank* in support of the region's broader ambition of *A Regional Collaboration for Health (ARCH)*.

1. Introduction

1.1 South West Wales

South Wales has long been nurturing a nascent Life Sciences cluster (DTI 2001) and has looked to develop the potential of the sector as part of a wider strategy for economic renewal (WAG 2005, WAG 2010). Significant investments by public and private sectors have established a substantial research infrastructure and new enterprise, much of it focused around the Swansea Bay City region and involving Swansea University's Medical School.

Most recently, regional efforts to develop the sector have focused upon 'smart specialisation' strengths including medical devices, informatics and wound healing. Entrepreneurial learning sits at the heart of these endeavours, working to commercialise academic research and enhance industrial collaboration. This chapter records how these efforts have been involved in the development of a Life Sciences and Health cluster within a sub-regional innovation system/ecosystem involving enterprises from a broad range of sectors.

This development is presented through *Understanding:* the insight established to inform interventions for sector development; *Acting:* efforts undertaken to create new enterprise with support of the Medical School; *Measuring:* and a summary of the impact it has had upon the regional economy.

1.2 Industrial History

The current dynamics of economic development in South West Wales can be traced back to the economic restructuring that saw the United Kingdom established as the world's first industrial nation (Mathias 2013). This revolution continued with subsequent contraction of the steel industry and the almost complete disappearance of the coal industry during the 1970s and 1980s, punctuating a trend of economic decline that had set in during the post-war period (Morgan 2001).

Subsequently, economic development policy in Wales has focused on pursuing inward investment with what Cooke and Clifton (2005) termed a 'field of dreams' approach of 'build it and they will come'. This produced significant impact (Braczyk, Cooke et al. 1998) (Salvador and Harding 2006) particularly during 1983-93, with Wales attracting 15-20% of inward-UK Foreign Direct Investment (FDI). One major investment could deliver significant employment to the surrounding region and much like the iron works of old could become the prime employer in a town or region.

However, this FDI revolution turned further as opportunities declined during the 1990s with a slowing UK economy (Young, Hood et al.) and emergence of competitor regions such as China and India (Chen 1996). This resulted in some overseas-managed manufacturing branch plants relocating from Wales to regions with lower cost bases, with impacts on communities similar to the pit closures previously experienced. Observers noted weaknesses in the 'embeddedness' of such activity (Phelps, Mackinnon et al.), together with imbalance in the focus given to indigenous enterprise and clusters (Cooke and Clifton 2005).

1.3 Knowledge Economy

The ambition to transform the Welsh economy to one with a greater capacity for Research & Development and Innovation was set over a decade ago by the Welsh Assembly Government with *A Winning Wales* (WAG 2004b). Actions stemming from this strategy included implementation of an Entrepreneurship Action Plan and a fund to develop new ventures from the output of university research. Much focus was given to Information Communication Technology (ICT) and 'Green' sectors, though with wider efforts to support new and existing growth sectors and clusters.

During this period Cooke, Kaufmann et al. (2006) described the emergence of Regional Science Policy that the Welsh Government (WG) came to with its strategic agenda, *Science for Wales (WAG 2009).* This placed 'Life Sciences and Health' as a Grand Challenge area to be tackled though the EU approach of Smart Specialisation, and the associated concentration of investment into excellence. Programmes such as *Sêr Cymru* (providing funding to attract leading researchers) and the restructuring of the *Health and Care Research Wales* Research Infrastructure have stated the intention to build capacity and maximise impact. This approach provides a mix of industry and cluster policy development objectives discussed at the time by Cooke (2004a), and more recently by Ketels (2013), with knowledge transfer and commercialisation core components of the strategy. The inherent complexity, long-term nature and the fact that meaningful impact of such endeavours may not be seen for years after initial investment have been noted by Huggins and Kitagawa (2012). This is especially important for a sector where innovations can require years, or even decades, of effort.

More recently the Welsh Government's (WG) strategy for economic development has become more sector focused, and is aimed towards nine key sectors, including Life Sciences, which it recognises as being particularly important for its additional health and broader societal benefits;

> *"The Life Sciences sector is an important driver of economic growth and improved well being. It serves large global markets which are growing quickly, driven especially by population growth, changing demographics and increasing expectations from medicine and therapy"* (WG 2013) p.18

WG has established a sector panel to develop and implement a strategy and action plan to harness the potential of Life Science for Wales as a whole with the vision "to facilitate the growth of a dynamic life science ecosystem, leveraging financial investment where industry, academia, clinicians and government collaborate and deliver a sustainable economy and excellence in healthcare innovation" (WAG 2014). To achieve this vision, WG has embarked upon a number of strategic initiatives including notable investments to build upon strengths across the sector. The attraction of talent, and development of indigenous knowledge and intellectual property are central to two of the major pan-Wales interventions of the Arthurian Investment Fund and *Sêr Cymru*.

1.4 Life Sciences in Wales

In 2001, the UK Department for Trade and Industry (DTI 2001) identified a nascent biotechnology cluster within Wales. Although this did not appear in the 31 key UK clusters described in the more recent McKinsey (2014) review, it is seen in subsequent analysis by

consultants (SQW 2014) this also applied to many clusters identified in 2001 by DTI, including ones that had grown during the intervening period.

In parallel with this observation, although not explicitly targeted in the Welsh Assembly Government Economic Development Strategy, *A Winning Wales* (WAG 2004a), the sector, defined as 'pharmaceuticals/bio-chemicals' was identified as important for future economic growth (WAG 2005).

Active Enterprises by Priority Sub-Sector - Life Sciences[1,2,3]

	2005	2006	2007	2008	2009	2010	2011	2012	2013	% of 2013 total	Change 2005 - 2013	Change 2012 - 2013
Wales:												
Industrial Biotechnology	35	35	35	40	35	30	25	25	20	7.3%	-38.9%	-12.0%
Medical Biotechnology	95	100	105	150	130	120	120	110	110	40.0%	13.7%	-1.8%
Medical Technology	115	110	110	110	110	110	95	100	100	36.4%	-12.9%	0.0%
Others (inc Pharmaceuticals)	25	25	25	25	30	30	30	40	45	16.4%	80.4%	12.5%
Total Life Sciences	**270**	**270**	**275**	**325**	**305**	**285**	**270**	**275**	**275**	100.0%	**1.6%**	**0.0%**
UK:												
Industrial Biotechnology	460	450	460	435	400	360	335	330	345	5.2%	-25.0%	4.2%
Medical Biotechnology	2,490	2,605	2,690	3,300	3,175	3,090	3,015	2,980	2,955	44.3%	18.7%	-0.8%
Medical Technology	2,405	2,380	2,380	2,180	2,385	2,320	2,300	2,305	2,345	35.2%	-2.6%	1.6%
Others (inc Pharmaceuticals)	540	545	550	490	625	675	755	895	1,020	15.3%	89.3%	13.8%
Total Life Sciences	**5,895**	**5,975**	**6,080**	**6,405**	**6,585**	**6,450**	**6,410**	**6,515**	**6,665**	100.0%	**13.1%**	**2.3%**

Source: Inter-Departmental Business Register, Office for National Statistics

Table 1: Life Sciences Enterprises by Subsector

Employing 10,000 people across Wales and annually contributing £2bn to the economy (WAG 2014), the Welsh Life Sciences sector is developing rapidly, particularly in comparison to other sectors which have suffered badly during recent years. In Wales, the sector has seen significant investment and growth including a number of major regional developments. This has resulted in growth in Gross Value Added (GVA) of circa 13% per annum across the sector despite the chronic broader economic conditions (Table 1 above).

Over 80% of sector employment is within medium/large enterprises. However the Welsh 'ecosystem' also comprises scores of smaller companies and sole traders, many of whom are also globally active. While the South East of England accounts for the largest share of the sector there are strengths across the UK, including within Wales a significant proportion of medical technology activity (Table 1). The comparative strength of this sub-sector is highlighted when compared in more detail against other UK regions (see Fig. 1 below).

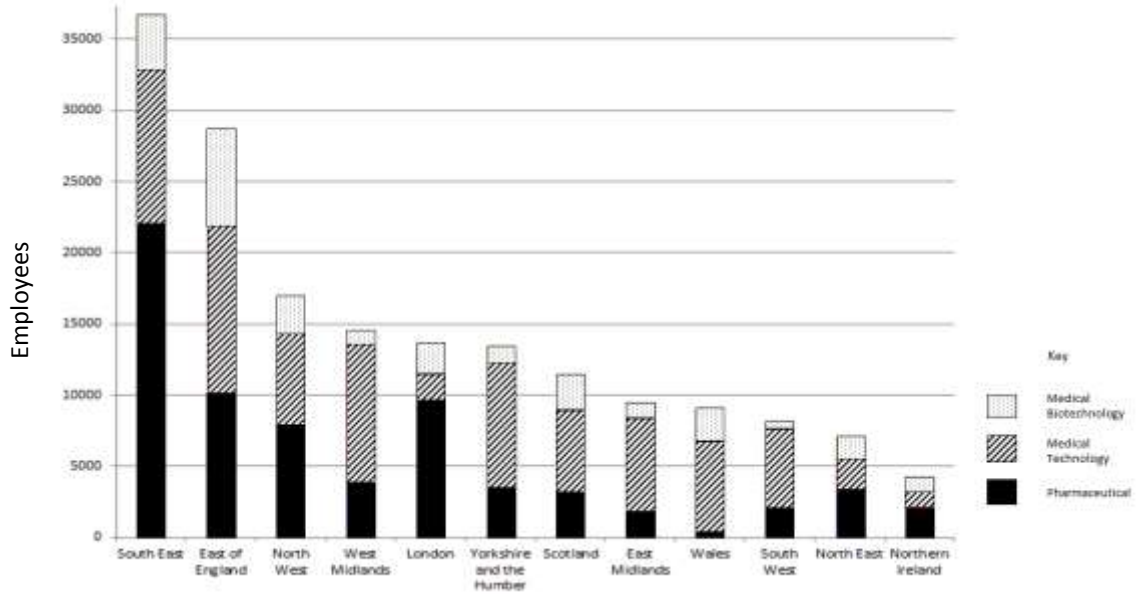


Fig. 1: Sub-sector employment by region – Source: (Govt 2014)

The regional diversity within the sector ranges from global companies manufacturing medical supplies such as Ortho Clinical Diagnostics, through to indigenous enterprises such as Biotec Services International providing specialist clinical trials supplies and support.

The relatively low showing for the pharmaceutical sub-sector in Wales suggested by Figure 1 hides a mass of associated activity in clinical trials, drug discovery and toxicology research which is featured elsewhere. Indeed, the quality of work across Wales in the development of new diagnostics and therapies is world-class. For example, Cell Therapies Ltd, a start-up founded by a Nobel Prize Winner for Medicine, has undertaken part of its development work both in Cardiff University and Swansea University's Institute of Life Science.

The 'South West and Central Wales' region is home to a diverse Life Sciences enterprise ranging from early-stage academic spin-outs through to major employers producing products for household names. ILS for example works with some 250 enterprises ranging from local specialist consultants through to multinationals. While the regional employment within core Life Science is the smallest amongst Welsh Government Priority Sectors, its high GVA per worker, significant growth potential and crossover with other high-value sectors are important drivers.

1.5 Institute of Life Science (ILS)

The Institute of Life Science[1] has been developed as a partnership between Swansea University's Medical School, Abertawe Bro Morgannwg University Health Board (ABMUHB), Welsh Government (WG) and the private sector to develop the potential of Life Science research and innovation to help improve the wealth and health of Wales. These efforts have been combined with broader WG efforts to build a Life Science 'Ecosystem'.

This initiative aims to help address regional limitations in regional innovation capacity including the comparatively low level of Business Expenditure on Research and

[1] http://www.swansea.ac.uk/ils/

Development (BERD) and the requirement for new opportunities and ventures to support sector development. This underscores the importance of local higher education institutions noted in the WG Knowledge Economy Nexus review of the interplay between Welsh higher education and industry (WAG 2004b).

Since 2004, the ILS initiative has created a number of facilities including biomedical laboratories, a dedicated clinical research facility, a medical imaging research suite, and business incubation/growth. Co-located with clinical facilities and expertise of the ABMUHB Singleton Hospital site and the wider academic resources of Swansea University, ILS is supported by a team engaged in commercialisation of research and development of other industrial collaborations. In this respect ILS has aimed to create an entrepreneurial learning environment where the boundaries of academia, industry, health service and other actors innovate together.

The ILS facilities have been realised through £37.9m of investment from Welsh Government and European Structural Funds (via European Union Objective One and Convergence Programmes), with the technology transfer and research activities sustained through reinvestment of research and commercial incomes. Capabilities, such as ILS, aim to provide intellectual output to support regional sector development. This, however, needs to be aligned with the 'absorptive capacity' of firms and the broader industrial sector within the region to harness this for its benefits to be captured locally. In essence, this requires an alignment between the existing and growing sectors to optimise the impact of university output and wider relevant interventions. The next section describes efforts undertaken to develop this *Understanding*, to inform strategy and delivery of actions including the Institute of Life Science.

2. *Understanding:*

2.1 Regional Learning Partnership/Life Science Exchange

Vibrant sustainable knowledge-driven clusters have been demonstrated as drivers of productivity and innovation (Porter 2000) and engines of new venture formation (Delgado, Porter et al. 2010), so an interest in them from policy-makers for economic development is understandable. However, research into Life Sciences clusters has often focused on major US and EU clusters (Cooke 2004a), and there exists some scepticism of the effectiveness of interventions for their development (Martin and Sunley 2003) (Brakman and van Marrewijk 2013). A core concern has been 'fuzziness' of the cluster concept, while other commentators acknowledge the gap between theory and practice (Swords 2013), and the need for a consideration of specific local context (Ketels 2013).

Recent regional efforts have provided important learning for future development with a review of interventions noting limitations in absorptive capacity (Cooke 2004b) and loss of focus upon the knowledge-economy mission (Morgan 2013). To help address the issues identified, detailed understanding of the sector has been developed, through the work of the Regional Learning Partnership (RLP) and MediWales. This has involved the surveying and interviewing of diverse sector companies in the region, along with focus groups examining key sub-sectors. The intention of this work has been to use the insight gained to resolve the

challenge of 'fuzziness' in the concepts involved, and deliver both regional and sector-specific perspective in tailoring interventions attuned to absorptive capacity

2.2 Regional Learning Partnership (RLP) Survey

The purpose of the RLP report was to scope and understand the 'Skills Pipeline' into the regional Life Sciences sector. The inherent lead time of affecting major change within a regional skills base is a significant challenge in supporting the development of rapidly developing sectors such as the Life Sciences. This is underlined by the fact that secondary school pupils currently making important subject choices may not enter the labour market for a decade, if they continue through into further and higher education. Furthermore, the complexity of the sector, overlapping into ICT, Advanced Manufacturing and other Services required broad consideration of the skills involved.

The research was undertaken to provide recommendations to assist the region in optimising its provision and subsequent benefit from the skill base required to harness the potential of the sector. The study underpinning the report involved analysis of the current supply of qualified individuals from schools, further education and higher education institutions, together with a survey of enterprise needs across the sector.

The RLP research involved a detailed survey and interviewing of a representative forty-six enterprises across the region. Alongside the skills and workforce aspects of the research, the research and development (R&D), innovation and networking activities of companies were also surveyed to provide a more detailed understanding of the dynamics involved.

While relatively small, this survey highlighted a number of key issues, not least the interdependence between Life Sciences and other sectors across the region. With respect to roles within companies, a significant proportion of Life Sciences employment related to 'manufacturing' roles (Table 2).

Sub-Sector / Roles	Number of companies	Technical Roles (FTE)	Managerial Roles (FTE)	Administrative Roles (FTE)	'Other' Roles (FTE)
Medical Devices	18	46.8	49.3	46.3	94.3
Specialist Services	10	34	17	11	6
Human Therapeutics	6	49	15	17	2
Manufacturing	8	93.8	60.3	60.1	173.7
Veterinary/Environmental	1	0	1	1	0
Clinical Research	3	58	29	26	1
Other	12	47	14	12	16

Table 2 Employment breakdown by sub-sector

While the findings summarised in Table 2 demonstrate the medical technology nature of the sector within the region, it also points encouragingly to the fact that there are enterprises with their entire value chain from basic R&D through to manufacturing and distribution within the region. This is discussed further in the following section.

Much focus is understandably given to the specialist scientific skills required to support R&D, and this provides an important linkage between the sector and academic institutions. However, as shown in Table 3, presenting planned recruitment by surveyed companies, the majority of roles fall outside of this scope. While this provides a broader challenge for skills supply, it also highlights the wider employment potential for the sector beyond Science, Technology, Engineering, Mathematics, and Medicine (STEMM)-trained individuals.

Sector	Technical	Managerial	Administrative	Other	Total
Medical Devices	***16.25***	***11.17***	***11.78***	*8.00*	**47.20**
Specialist services	*2.00*	*0.40*	*0.80*	*1.50*	**4.70**
Human Therapeutics.	*12.75*	*5.37*	*3.38*	*0.00*	**21.50**
Manufacturing	*4.25*	*2.18*	*2.67*	*1.00*	**10.10**
Veterinary/Environmental	*0.50*	*0.50*	*0.50*	*0.50*	**2.00**
Clinical Research	*4.75*	*2.38*	*1.37*	*0.00*	**8.50**
Other	*7.00*	*0.00*	*3.00*	***9.00***	**19.00**
Total	**47.5**	**22**	**23.5**	**20**	**113**

Table 3 Anticipated recruitment breakdown by sub-sector

The Report's recommendations included the establishment of a group to support the sector, together with specific actions aimed across further and higher education, schools and other stakeholders. Such a group has since been established as the All Wales Life Sciences Skills Group, with strong regional involvement and engagement with Welsh Government's departments of Economy, Science & Transport, and Education & Skills. A key response to the Report's recommendations has been the development of the 'Talent Bank' in partnership between Gower College (further education) and Swansea University's Medical School. The concept involves the creation of a dedicated Life Sciences and Health FE College co-located with the University, Health Boards and industry. Intensified curricula informed and delivered in partnership with practitioners are intended to support skills supply from for students aged 16 to18 through to continuing professional development as part of an integrated sector-focused lifelong learning system.

2.3 Life Science Exchange

Alongside the RLP research, wider actions have been taken to understand the dynamics and opportunities of the regional sector, a prime example of which is Life Science Exchange (LSE)[2]. The aim of LSE was to identify and develop academic, public and private sector knowledge exchanges that effect economic change. The LSE work has involved a series of 'sandpits' (events bringing together experts from a range of disciplines/sectors to explore a specific topic or problem space) and quarterly focus groups examining specialist areas of diagnostics, ehealth, medical technology, neuroscience, pharmaceuticals, and regenerative medicine, aligning with the identified Welsh smart specialisations. This created sub-sector-specific entrepreneurial learning groups that has informed understanding and in itself has provided a learning environment for participants.

[2] http://www.swansea.ac.uk/life-science-wales/

The output of the Life Science Exchange is a body of sector intelligence that represents the collective expertise of a wide range of expert contributors. This purpose of the work is to inform future policy and planning across the sector and will help to align support activities with the needs of companies, universities and health care providers. Specific, actionable recommendations have been provided in the detailed reports provided by the Life Science Exchange to the WG with the ultimate aim of improving innovation, health, and wealth in Wales.

The work has highlighted the important role of the Welsh National Health Service (NHS) in providing access to clinical expertise, facilities, and ultimately as a customer. Opportunity for greater engagement and clinical access for R&D was noted, along with scope for greater evaluation and adoption of Welsh innovations.

There was a recognised need for the engagements instigated by the Life Science Exchange to continue into the future. In some cases, specific challenges and opportunities needed to be crystallised into detailed proposals with specific objectives, deliverables, budgets and time-scales. A number of organisations have expressed the desire to maintain the momentum of their respective focus groups as Special Interest Groups operating under the Life Science Exchange brand or unique branding (e.g. Clinical Trials Services Wales).

The Life Science Exchange process has brought together hundreds of stakeholders in a sub-sectoral approach to the Welsh National Innovation System. This has resulted in a multitude of collaborations, projects, inward investment opportunities, and special interest group formations, in addition to securing multiples of investment in funding for Wales. There was a view found amongst participants that processes such as the Life Science Exchange should be continued to be supported by the WG and the process could be held up as a shining example of best practice for knowledge exchange for other sectoral systems of innovation. The Life Science Exchange model is a simple and straightforward mechanism for any regional government to adapt and implement with the hope of improving innovation, skills, networks and knowledge exchange.

3. *Acting:* Institute of Life Science

3.1 ILS Overview

Since its inception in 2004, ILS has established research and innovation capacity to assist in developing a regional cluster built from enterprise including academic spin-outs, existing and new indigenous enterprise, and inward investment. The focus of the ILS Phase 1 (2004-2008) project was to provide specialist medical research laboratories along with business incubation facilities to support academic-industrial collaboration. This coincided with the development of a research focus in health and bio-informatics underpinned by the IBM Blue-C supercomputer infrastructure. Phase 2 (2009-15) involved the development of an expanded research infrastructure and incubation capacity, including a clinical research facility, medical imaging suite and informatics research offices.

Alongside the insight from the RLP research and other efforts, ILS has recognised weaknesses noted in previous regional initiatives by commentators. Thereby it can be seen as trying to learn from experience through ‘experimentalism’ of the form described by (Henderson 2000). Efforts have been made to optimise absorptive capacity by aligning an

R&D focus with the sector in the region to address challenges noted by Cooke (2004b), while more robust management maintains the focus of mission and monitoring, in response to issues noted by Morgan (2013).

The apparent lack of involvement by Technium (a regional initiative to develop a network of innovation centres) with the wider innovation system actors, such as financiers, patent attorneys and business development specialists identified by Cooke (2004b), has led to ILS actively pursuing engagement from the outset, as noted in the following section. This sought to create systemic linkages across the sector within the region, nurturing new and supporting existing indigenous enterprise while attracting inward-investing opportunities. Examples of this include the 'Scinapse'[3] partnership providing professional services and a sector-specific cohort of the LEAD Wales initiative[4]. Both programmes support the entrepreneurial learning agenda, with the former providing leading expertise to support businesses, and the latter developing leadership within SMEs to promote sustainability and growth.

The nature of engagement with ILS, both for existing companies and start-ups relates significantly to scientific expertise and specialist facilities, as shown in Figure 2 from Davies et al., Huxtable-Thomas et al. (2015) citing survey and project monitoring data.

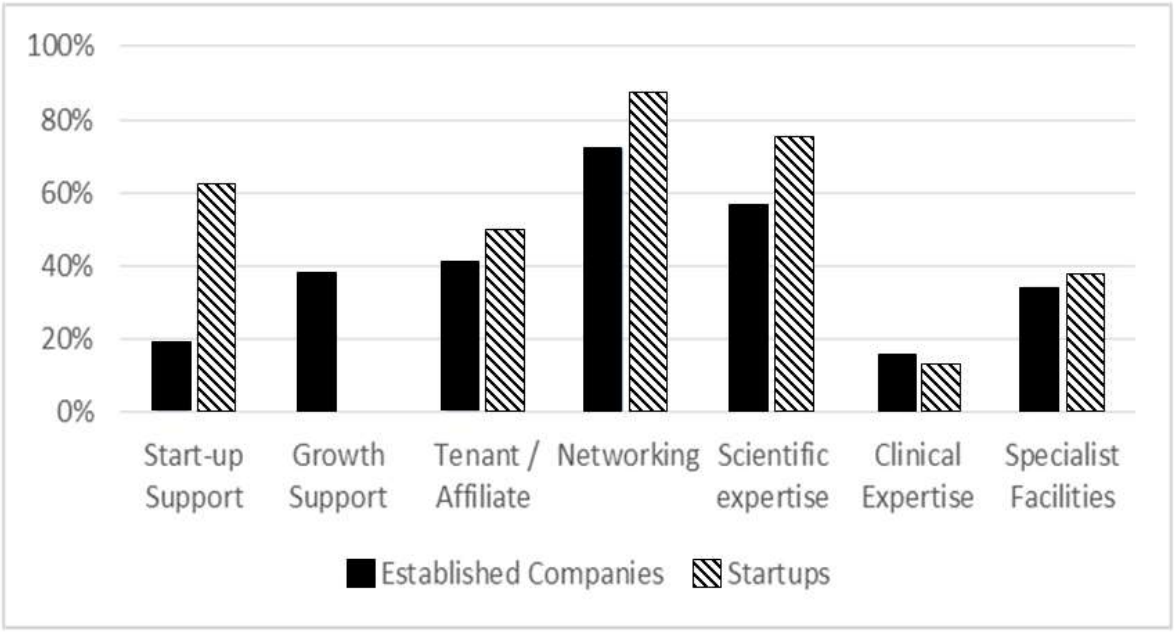


Fig. 2: ILS support uptake by engaged existing enterprises and start-ups

However, the predominant nature of engagement with ILS has been to support networking amongst enterprises, researchers and other actors suggesting ILS is playing a more complex role within a system rather than having simply separate bipartite relationships with supported companies. The involvement of start-up enterprises in such myriad relationships suggests an entrepreneurial learning milieu amongst entrepreneurs, academics and other ecosystem participants.

[3] http://www.lifescienceshubwales.com/members/scinapse/
[4] http://www.swansea.ac.uk/reis/case-studies/lead-wales/

3.2 ILS Engagement

The nature of the engagements undertaken by ILS described in the previous section reflect its assets and mission, though how this relates to the sector it serves requires further consideration to determine whether it is actively supporting development of 'embeddedness'.

During the period 2004 to 2013, ILS has worked with 279 enterprises active in the Life Sciences and Health sectors across the South West Wales region, with 243 enterprises (87%) qualifying as small and medium sized enterprises (SME) based on indicator performance as noted in end-project evaluation by The European Consulting Company (TECC)/Trilein June 2015). This grouping is comparable in scale with the Scottish cluster at the turn of the century (Cooke 2001) though with a different nature to its 'core'.

These core enterprises span a broad range of segments, with a core of medical technology and medical bio-technology reflecting the broader sector in Wales. A recent exercise used an adaptation of the Cluster Map developed for Life Sciences in Munich, Germany (Cooke, Kaufmann et al. (2006), to present the makeup of enterprises engaged with the cluster around ILS (shown in Figure 3 below). This used the same mapping with service providers, interrelated industries, supporting organisations and related clusters (as indicated in the key for Figure 3). This includes many of the actors seen in the conceptual bioscientific and biotechnological value chain proposed by Cooke, Kaufmann et al. (2006).

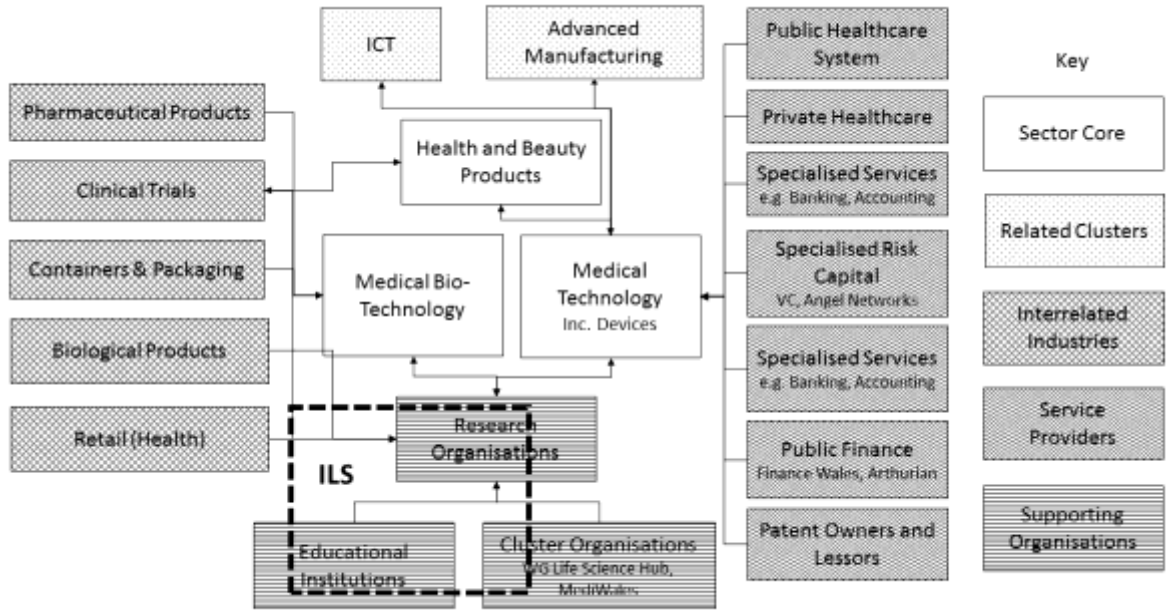


Figure 3: Regional life sciences and health ecosystem mapping

The Cluster Map, and the engagement of ILS captures the breadth of organisations within the ecosystem. Notable actors include the National Health Service (NHS) (as the Public Healthcare System) as a major consumer and partner in the development of Life Science innovation; a range of enterprises engaged in various activities in clinical trials; and the role of public finance, including the recently established Arthurian Investment Fund. ILS itself features across a number of roles, operating simultaneously as a Research, and Educational and Cluster Organisation.

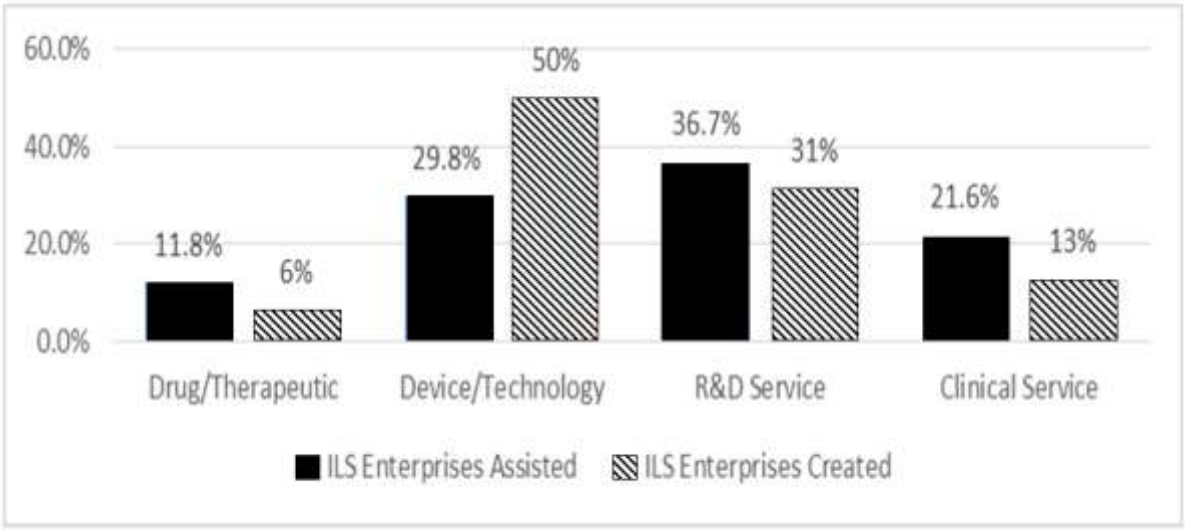
The importance of a diversity of actors within the cluster is important for success, though with world-class scientific talent as a critical ingredient, as highlighted by Audretsch (2001) in a review of US biotechnology clusters as a complementary factor to support commercialisation of knowledge. The ILS ecosystem certainly presents such diversity, while a recent strong performance of associated researchers in the Research Excellence Framework (REF) 2014[5] and major UK Research Council (RCUK) investments suggest that research quality and scale is developing in parallel.

3.3 Ecosystem enterprise contribution

The creation of a new enterprise is just one mechanism to develop life science opportunities, and most of ILS's work involves supporting existing enterprises, large and small. However, new companies are an important mechanism for commercialising research in an entity dedicated to venture and harnessing opportunities within the locale. Indeed, even across international borders, start-up opportunities are being actively pursued and poached to embed their innovation and job creation potential.

Start-up enterprises are therefore important, if somewhat longer-term in their impact. Due to testing and regulation new ventures commercialising medical products have long lead times, typically 10-20 years with new drugs requiring on average $1billion of investment (BIS 2011). Therefore downstream impacts of new ventures can take a significant time to be realised. Therefore for an initiative such as ILS to have a major impact in the near-term requires engagement with a broad portfolio of ventures throughout each stage of commercialisation.

To date, assistance provided by the ILS (during the Phase 2 period 2009-15) has resulted in the creation of sixteen new enterprises primarily in the fields of medical devices and drug discovery. Research suggests that, despite a recent slowing in start-up activity across the sector (Mobius 2011) (mainly due to a drop in University spin-outs across the UK), the survival and success rates amongst technology firms (excluding those dedicated to specific are encouraging. Figure 4 shows the breakdown of ILS start-ups by activity, in comparison with the wider community of existing enterprises engaged by ILS.



[5] Research Excellence Framework 2014, www.ref.ac.uk

	Drug/ Therapeutic	Device/ Technology	R&D Service	Clinical Service
ILS Engagements	29	73	90	53
ILS Start-ups	1	8	5	2

Fig. 4. ILS enterprises assisted and created by segment

The make-up of the new ventures established through ILS (Fig. 4) presents a diversity reflecting the broader regional ecosystem, predominantly based upon medical devices along with clinical and other services, while only one enterprise related to pharmaceuticals.

Interestingly, two of the largest spin-outs each employing over twenty people were reincarnations of previous enterprises which had 'failed'. This emphasises the importance of an enlightened entrepreneurial culture which recognises risk, learns from experience, and celebrates effort not just success. A further interesting observation from this albeit relatively small community is the nature and extents of linkages they possess. Figure 5 shows that linkages with external research activities constitute the most prevalent type of linkage. While this is to be expected (Mian 1996), it is the relatively high proportion of firms reporting multiple linkages which suggests greater embeddedness within the region that suggests a clustering effect. This is supported by the fact that just under a third (5/16) firms originated as university spin-outs.

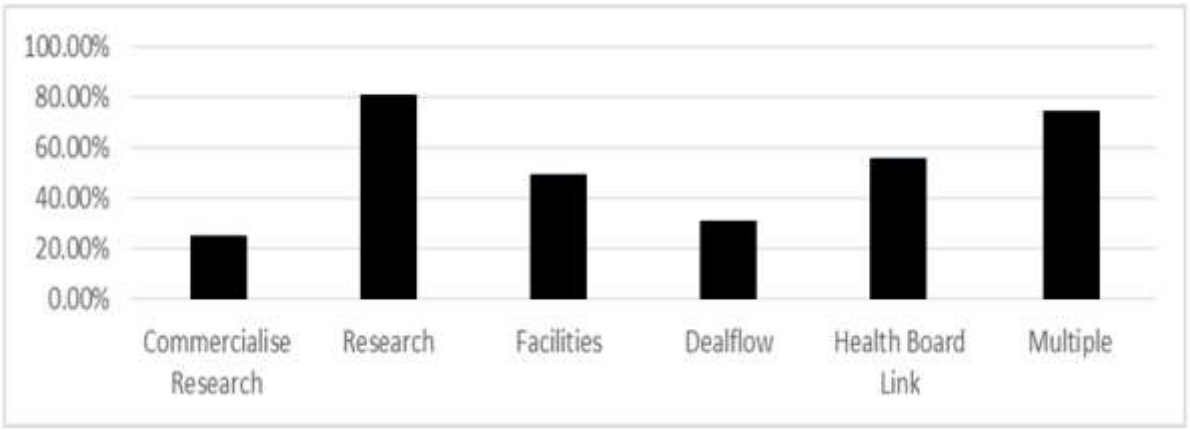


Fig. 5 ILS enterprises created: linkages by type

Recognising, let alone appreciating or understanding, this complexity is a challenge for many observers, while the long-lead times and inherent risk of life sciences R&D/innovation requires patience and volume to provide likelihood of success.

The research also highlighted the long-standing finding by Teece (1986) that benefits extend beyond the innovating firm. Two of the companies in question had established manufacturing relationships with established firms (including a branch plant of a multinational enterprise) in the region, resulting in seventy new jobs. Another two companies were in earlier exploratory stages of similar arrangements. This finding suggests that the new enterprises are contributing to the embeddedness, not only of themselves but also to that of other employers beyond the core sector.

3.4 Wider engagement: NVI Wales

The earlier part of this section has shown how ILS has aimed to support the development of Life Seciences and Health, with networking within the regional ecosystem supporting an entrepreneurial learning ecosystem. However, it should be noted that an internal view of activity in the region has been complemented by numerous external engagements to support entrepreneurial learning. An example of this is involvement in the National Virtual Incubator (NVI) Network. NVI Wales, supported by WG, is part of a flagship initiative of Cisco's British Innovation Gateway ("BIG") programme. The NVI network, connects thirteen business incubation centres and research institutions around the UK (called 'NVI Nodes'), via state-of-the-art Cisco video conferencing technology.

The purpose of the NVI is to bring organisations together in collaboration to boost levels of UK research, innovation and economic growth. NVI is central to the development of the UK's emerging innovation ecosystem. NVI Wales (or the Welsh node) is based in Swansea University Medical School at ILS and it joined the network as a specialist communication point for life science and ICT start-ups and SMEs. Entrepreneurs in the Swansea City Region and across Wales can visit the Welsh node to connect with other organisations in the UK wide network in order to share resources, pool ideas and develop new business partnerships.

NVI activities include a seminar programme which attracts both UK and internationally renowned speakers. These seminars aim to expose businesses in the City Region and the national network to the latest technologies and emerging trends. The NVI hosts monthly 'Peer to Peer' sessions which offer local businesses the opportunity to talk to peers from across the UK. Topics covered range from Big Data, Gaming and Healthcare Apps to Internet of Things (Elliott, Levin et al.). These sessions help to raise the profile of the City Region's companies, facilitating direct contacts to other UK companies, universities and customers.

In aiming to support and encourage entrepreneurship and enterprise, NVI Wales provides additional support to members in the City Region and Wales through a robust pipeline of business support workshops and one to one sessions. NVI Wales has recruited a number of private sector companies and business support organisations as mentors to provide this specialist advice for its members. Topics covered by mentors include: finance, funding, product development, innovation, IP, marketing, and entrepreneurship.

NVI Wales has developed and delivered a number of UK wide innovation workshops. These workshops have brought together business leaders, academics and the NHS to drive entrepreneurship and innovation by encouraging delegates to generate and co-develop new ehealth solutions, ranging from healthcare apps to wearable devices. NVI Wales has thereby provided the Swansea City Region and ecosystem with a position in this dynamic UK wide digital ecosystem helping to drive and stimulate entrepreneurship, collaboration, innovation and business development.

4. *Measuring:* Emerging Impact

4.1 ILS measurement

Previous sections have described the challenges and opportunities to which the region is responding, together with activity undertaken to develop a sub-regional innovation system/ecosystem. The RLP research explored the nature and potential of the nascent cluster, while the ILS data suggest enterprises are being developed and embedded with the broader 'ecosystem' around them. However, it is the sought economic contribution that is of interest to policy-makers and the wider community. To ascertain the scale and nature of this impact, a study has been undertaken examining the ILS activity for which comprehensive monitoring data exist. Only through such assessment can it be determined whether such interventions are contributing effectively.

The economic impact of universities on their communities has long been studied (Elliott, Levin et al. 1988) with increasing interest in their contribution through development of knowledge-economies (Berman 1990, Roberts and Eesley 2009). Huggins and Cooke (1997) clearly notes this in a paper analysing the economic impact of Cardiff University, with specific regard to linkages with the Cardiff Business & Technology Centre (though in this current context the Cardiff MediCentre at the Heath Hospital would be a more relevant linkage).

As ILS is a publicly-funded initiative it has maintained records of its activities which can feed readily into evaluation. Official Government guidance for evaluation of public programmes and projects in the United Kingdom (including Wales) is provided by the Her Majesty's Treasury Green Book (HMTreasury) This aims to provide best practice for appraisal and evaluation of projects of all types and sizes, covering their economic, financial, social and environmental aspects.

The European Union, which co-funded ILS through Structural Funds, also offers guidance relating specifically to economic development initiatives in *The Guide: The Evaluation of Socio-Economic Development* ((EU 2013). This guidance provides an in-depth resource for the planning and undertaking of evaluations. Although it is aimed primarily at the programme level (that is, in consideration of multiple interrelated projects), it provides a useful resource for all types of evaluation. In addition, data collection for Structural Funds projects involving innovation activities aligns with a wider framework presented in the Oslo Manual (OECD 2005).

A further European Commission document, *Guide to cost-benefit analysis of investment projects* (EU 2002, EU 2014) provides specific guidance on a range of interventions including investments as diverse as ports and airports, museums and archaeological parks. In relation to 'Industrial Estates and technological parks', it is suggested that such interventions are evaluated with a time horizon of at least twenty years and that the wider social benefits, such as improved entrepreneurial skills are included. This is consistent with the vision of ILS (and the theory of cluster development), that the most significant benefits would be reaped in the long-term.

4.2 Study Approach

The counterfactual to the ILS efforts would have simply been a region without a College of Medicine and the associated activities including the research that spawned new enterprises. However, some or different benefits may have been received by the region through other activities using the same initial resources. Understanding this within the complexities of a myriad of interventions is a challenge which also exists at Programme level (DTZ 2010).

Using evaluation practice drawn from the Her Majesty's Treasury Green and Magenta Books, the impact of ILS has been examined against the initial pump-prime European Structural Funds/WG investment made over relevant time horizons and a defined region. This has been taken as fifteen years (2004-18) and twenty years (2004-23), with the geographical area defined as the South West Wales region. However, as discussed earlier, it should be noted that initiatives of this nature are long-term endeavours and their impact would be noted over a horizon of decades rather than years, with impact across a wider area. Furthermore, the indirect impacts of the activity are important and can be considered through multiplier effects.

Without sight of alternative investment opportunities available at the time, it is only possible to examine the cost/benefit of the intervention. This can then be given rigour by adjusting for timings of benefits (discounted using the 3.5% Social Time Preference Rate discount factor), making appropriate adjustments for deadweight, substitution and displacement, and testing sensitivity of assumptions.

To focus on impact providing additionality to a region, the base scenario of this review applies a 50% factoring, reducing levels across all gross reported impacts. This factors potential effects of deadweight, displacement and substitution which may be occurring, and which due to inherent complexity of activities cannot be calculated otherwise. This level is in line with initiative (EU 2002) and programme level ex-post evaluation (WG 2012) and research examining current programme interventions (Oldbell3 2012).

To support analysis of the impact, a set of scenarios have been applied ranging from optimistic to pessimistic, together with a base, allowing sensitivity to key assumptions to be assessed. This involves adjustment of key parameters as presented in Table 4;

	Scenario		
	Low (Pessimistic)	Base	High (Optimistic)
Adjustment reducing Outputs for Deadweight, Substitution and Displacement	60%	50%	40%
Multiplier for In-direct Employment	0.2	0.5	0.6
Projected Combined Facility Value (Market Value at End of Evaluation Time Horizon)	10,000,000	12,000,000	15,000,000

Table 4: Cost/benefit scenarios key parameters

4.3 Calculated Impact

As described in earlier sections, the primary stated impact of ILS has been employment creation, delivered by levering additional investment into the region from UK and EU research councils, venture capitalists and other funders. Employment creation data from the

Phase 1 and 2 projects, together with associated wage information and residual value of the project therefore provides the basis of this assessment, calculated as if benefits conclude at the end of the time horizon (i.e. not considering any ongoing employment).

The activities of the ILS initiative during the Phase 2 period (2009-2015) contributing to the research and innovation capacity of the Welsh Life Science sector are noted in the independent end-project evaluation (TECC 2015), and as emanating outwards from its South West Wales 'Convergence' region hinterland. Key outputs of the ILS initiative are noted as;

- Assisting over 274 enterprises from micro-businesses through to multinationals
- Contributing to the development of over 37 new pieces of intellectual property
- Helping create 16 new enterprises
- Supporting the creation of 510 direct jobs and scores more within the wider community through multiplier effects
- Establishing a research and innovation capacity that will help sustain the regional Life Sciences cluster with new knowledge and skills during further phases of the initiative.

The above builds upon activities undertaken during the Phase 1 period (2004-2008), during which 193 jobs were created, 21 collaborative projects established and 16 new enterprises created, alongside a new R&D facility housing industrial and academic research together with incubation facilities.

The impact of ILS as an initiative has delivered a range of impacts across short, medium and long-term (ongoing) time horizons. The following analysis quantifies impacts drawn together under the categories of Construction Phase; Academic, R&D and Commercialisation; and Innovation and Enterprise benefits, as follows;

Construction phase benefits: The impact of the project during its construction phase derived from employment and the creation of new facilities. This employment impact has been quantified from project records, using sector wage information for the region from the relevant periods[6]. In addition, the facility realised has inherent value which is a potential benefit (taken as projected market value) at the end of the time horizon, either to provide continued benefit as present, or alternative use. At the peak of construction, 57 FTE workers were involved in delivery of the faciltiies, across prime and subcontractors[7]. This represents a relatively minor part (8%) of the overall employment related to the ILS activity.

This expenditure is noteworthy as it would have been a valuable contribution to the sector during a particularly challenging period (2009-11). Alongside the wage impacts, the construction activity resulted in materials expenditure with suppliers across Wales, and ultimately in delivery of the R&D facilities with a planned lifetime of 30+ years prior to refurbishment or renovation.

Catalysing academic research, development and commercialisation: Describing the economic benefits from employment within the project portfolios being led from academic centres. To avoid double counting, this factors solely employment and wage impacts and not

[6] https://statswales.wales.gov.uk/Catalogue/Business-Economy-and-Labour-Market/People-and-Work/Earnings/averageweeklyearnings-by-occupation-ukcountry

[7] Over 500 individuals in total were involved in the construction of the ILS2 facility, though the peak relates to the highest FTE value of individuals contracted for over twelve months by prime or subcontractors.

broader investments (such aas the UK Research Councils) which may include staff expenditure. Wage information for roles is available; however the assessment uses a lower value for similar roles in the wider economy, which together with adjustment for deadweight and displacement provides for conservative comparison. The Phase 1 project created 115 R&D jobs, rising to 385 by the completion of Phase 2 project in June 2015. This includes R&D roles created to support commercialisation of research into the new ventures described in previous sections. The direct impact of this employment is calculated on the basis of the role type within the region from the time of its creation[8] through to the time horizon, discounted accordingly.

Supporting Innovation and Enterprise: Describing employment, enterprise and innovation benefits derived from wider industry-based activities established through ILS. Again, to avoid double counting, this category of impact includes only wage impact as other data such as values of investments may also include staff and expenditure outside the region. 261 full-time roles were created which relate to this category in the period through to June 2015. Robust monitoring required by EU Structural Funds has clearly demonstrated that this impact occurred within the region, with clear relationship to the ILS actvity.

As this employment relates to a broad range of roles (as noted in RLP research referred to earlier), an average regional wage during respective years for the region is used[9], though the higher GVA per worker within the sector suggests this is a relatively conservative position. These same figures are used for calculation of indirect employment impact as they relate to the broader economy.

Employment created with ILS assistance for each of the above categories is presented in Figure.6. This shows steady development over the period with the growth of research communities at the completion of each facility. Employment growth in the wider sector can be seen as tracking the development of scale in R&D.

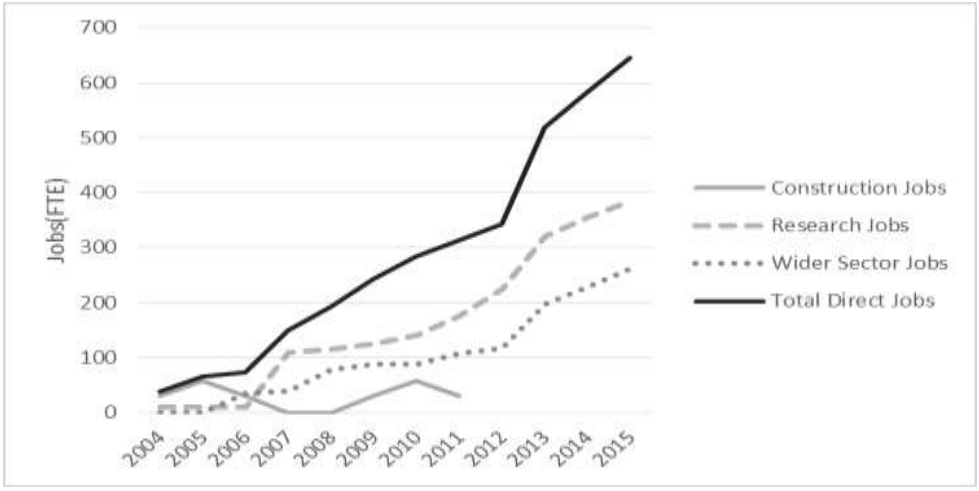


Fig. 6 Cumulative employment growth by job type

8 https://statswales.wales.gov.uk/Catalogue/Business-Economy-and-Labour-Market/People-and-Work/Earnings/averageweeklyearnings-by-occupation-ukcountry
9 https://statswales.wales.gov.uk/Catalogue/Business-Economy-and-Labour-Market/People-and-Work/Earnings/averageweeklyearnings-by-welshlocalareas-year

Using the ILS job creation and related sector wage data, the combined impact for each scenario was calculated, as shown in Table 5. This includes relevant adjustments for potential deadweight, displacement and substitution effects, with appropriate discounting of benefits. For all scenarios, the benefit/cost ratio shows a positive return growing across increasing time horizon which set against the context of weak economic growth in the broader economy is an encouraging position.

Benefits and Costs	**Base**		**Low**		**High**	
£,000	15yr	20yr	15yr	20yr	15yr	20yr
Direct Employment	91,287	150,431	73,030	120,345	109,544	180,517
Indirect Employment	37,294	61,607	11,934	19,714	53,704	88,714
Combined Employment	128,581	212,038	84,964	140,059	163,248	269,231
Combined (Discounted)	111,472	167,901	73,664	110,917	141,524	213,184
Facility Value	12,000	12,000	10,000	10,000	15,000	15,000
Investment PV	37,900	37,900	37,900	37,900	37,900	37,900
Net Present Value	**85,572**	**142,001**	**45,764**	**83,017**	**118,624**	**190,284**
Benefit/Cost Ratio	**3.26**	**4.75**	**2.21**	**3.19**	**4.13**	**6.02**

Table. 5: Benefits and costs by scenario

Many economic development interventions involve purely revenue activities and do not create facilities. Exclusion of facility value from this analysis provides positive returns, resulting in benefit/cost ratios of 1.94, 2.94 and 3.73 by Low, Base and High scenarios at the 15 year time horizon.

Further development associated with ILS, including the recently awarded Medical Research Council and Economic and Social Research Council Research Centres being incorporated into the ILS Data Science building will contribute further to the impact of the initiative. The inherent lead-time of bringing research to commercialisation and subsequent impact also suggests there may be further ventures resulting from research undertaken during the ILS Phase 1 and 2 project periods.

The above assessment is based on no such new enterprise or additional job creation post-June 2015, put simply, as if all employment benefit created ceases at the time horizon. However, as noted earlier, it should be anticipated from such initiatives that impacts are realised in the longer-term. This includes the enhanced capacity and activity in entrepreneurial learning, the recent short-term benefits of which are captured in activity to date but are intended to provide longer-term and wider impact beyond the ILS initiative and the considered time horzions.

5. Conclusions

This chapter has shown how South West Wales has worked to Understand, Act and Measure, in the development of a nascent Life Sciences and Health cluster. Core to this has been the development of an entrepreneurial learning environment drawing together academic, industrial and clinical communities to form new ventures.

The *Understanding* developed through the RLP research and Life Science Exchange has informed a range of activities aimed to align with the absorptive capacity of the region and provide additionality in economic impact, primarily through new employment opportunities. These exercises underscored the importance of a focus upon the development of a sustainable pipeline of opportunities, and alignment with the broader private sector to support venture development. The range of skills requirements noted by surveyed firms, along with the commercialisation challenges and opportunities faced by scientists and entrepreneurs have highlighted the importance of the entrepreneurial learning environment in realising value. The exercises also identified the specific segments where effort could be concentrated to align optimally with absorptive capacity and future development, which were smart specialisation areas including medical devices and ehealth technologies. Importantly, this understanding has helped inform a coherent integrated set of regional actions, enhancing research capacity, commercialisation capability and skills development to optimise absorptive capacity. The Talent Bank concept which emerged from this work exemplifies the long-term systematic approach, with lifelong learning embedded in an environment spanning from 16-18 year old student delivery though to continuing professional development. Integrated with higher education provision, Health Board delivery and industrial activity, Talent Bank expands the ILS entrepreneurial learning environment to a broader set of participants than those involved in previous phases.

ILS *Acting* across a broad cluster or ecosystem of activity has shown the required breadth of engagement noted above. The focus upon medical devices, and other related fields aligns with the Smart Specialisation approach described by Morgan (2013) and addresses the limitations of previous regional initiatives with regard to absorptive capacity and focus. It also means that ILS complements, rather than competes, with other regional work undertaken by colleagues in Cardiff University contributing other strengths to the sector. Indeed, this clearly manifests itself in the collaboration established between the two institutions through the Welsh Wound Innovation Centre (WWIC) at Llantristant which is built upon the further smart specialisation of wound healing.

The nature and activities of companies in and around ILS demonstrate the characteristics of a Sub-Regional Innovation System as proposed by Abbey, Davies et al. (2008). For example, the relationships already being established between ILS technology start-ups and manufacturing within the region demonstrate a contribution to broader embeddedness of enterprise and employment, beyond the core sector. As the number of such collaborations is growing, this suggests effective entrepreneurial learning is occurring amongst companies. In parallel, engagement through broader networks such as NVI Wales to wider UK, and LEAD Wales across sectors demonstrates externality and breadth to this learning.

Measuring the impact of the initiative has helped understand the effect it has had upon the regional sector and broader econmy, and informs its ongoing development and delivery. Robust collection of project data for monitoring and evaluation by funders has supported this exercise, highlighting the wider impact of the ILS entrepreneurial learning environment. While the intellectual focus of ILS may be in buildings at Swansea University, the impact discovered is distributed across the region and further sectors.

Sensitivity analysis undertaken in the assessment suggests a robust performance over the past decade. Even in the scenario involving combined pessimistic assumptions, it is shown that

the contribution to the regional economy is meaningful. The analysis has also shown that a decade of continued effort, without being knocked off focus by columnist commentators or political impatience, has allowed meangingful impact to be achieved from what are inherently long-term endeavours.

Furthermore, this chapter shows that ILS has embraced the most important lesson from (Morgan 2013) showing that Wales can learn from experience, with an approach to committed smart specialisation focused on a collective endeavour for innovation and regional economic development. ILS has therefore focused on development of activity and dealflow for the sector, aligned with and remaining in step with the region's growing absorptive capacity. This has been underpinned by entrepreneurial learning benefitting individual enterpreneurs, enterprises and the partnership itself.

The above learning has been embedded in the the recently-developed ARCH (A Regional Collaboration for Health) initiative which aims to extend the ILS entrepreneurial learning environment across the region from its origin in Swansea. Through actions such as Talent Bank, NVI Wales and the Life Sciences Hub, this environment will not only expand geographically but also extend its reach across generations and economic sectors providing a regional platform for lifelong entrprepreneurial learning.

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Please:

1. Check the acronyms e.g. DTZ?? EU EVALSED??

2. Distinguish in the text and in the references list between WAG 2004a and WAG 2004b

3. Add the location of the publishers

4. Check the Cooke reference. Is it a chapter in a book?

5. Check the Davies et al Ref

r. For all of the et al references, replace the et al with **all** of the authors' names (surnames amd initials)

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