University of Strathclyde Business School

Fraser of Allander Institute

The economic contribution of the pharmaceutical sector in Scotland

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Fraser of Allander Institute

Contents

Executive summary

The pharmaceuticals sector makes an important contribution to the Scottish economy. It has higher levels of productivity than the Scottish average and employs a significant number of people across Scotland – including in parts of the country (such as North Ayrshire) where job prospects have tended to be weaker than for the country as a whole.

As a result of these economic strengths, it has been identified by the Scottish Government as a key element of the life sciences Growth Sector.

According to the most recent figures available, Scotland has accounted for an increasing proportion of the UK pharmaceutical industry turnover and employment in recent years.

But its contribution extends far beyond the activities of the sector on its own. It supports a complex supply chain right across our economy with the wages and employment created helping to boost growth at both a regional and national level.

In this report, we conduct an economic impact assessment of the sector. This analysis – using a detailed technical model – enables us to estimate not just the direct contribution to Scotland's economy from the pharmaceutical industry but also its wider spill-over effects.

We estimate that the Pharmaceuticals and Related Sector;

- directly supports around 5,050 full time equivalent (FTE) Scottish jobs;
- supports a total of 16,500 FTE jobs in Scotland once wider spill-over factors are taken into account;
- supports a total of £2.7 billion worth of industrial output in Scotland; and,
- supports GVA worth £1.7 billion across Scotland.

However the sector does face challenges if it is to retain its position internationally and in the UK.

In particular, there is evidence to suggest that R&D activity has fallen in recent years (although the number and value of clinical trials undertaken has increased). This is a concern given the close connections between such activities and day-to-day operations. In the report, we consider the evidence on what attracts such activities to a country, including the important role of policy – not just in providing a supportive infrastructure for such activity (such as an educated workforce) but also by ensuring consistency between industrial and wider government policies.

Acknowledgements

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Introduction
Chapter 1

1.1 Background

The pharmaceutical sector is a major high-technology contributor to the Scottish economy.

The sector encompasses a wide range of activities from internationally leading research and development, through to manufacturing of pharmaceutical products and ultimately to sales, marketing and industry leadership.

It has been identified by the Scottish Government as an important contributor to the life sciences Growth Sector. Growth Sectors are areas of the economy where the government believes that Scotland has a distinct international comparative advantage.

Previous reports by the Fraser of Allander Institute have examined the industry's economic impact on Scotland and have gathered evidence on the scale of the sector over time. This updated study uses the most recent data available to examine its ongoing contribution to the Scottish economy.

It discusses growth in the sector and its performance against a broad range of indicators.

We assess the contribution of the sector to the Scottish economy, including not just the direct impact of the sector's own activities but the wider spill-overs across Scotland's business base. In doing so, we trace the connections between the sector and other Scottish industries.

Given the increasing focus of economic policy in Scotland on innovation and technology we also provide a summary of the sector's research and development activities.

The structure of the report is therefore as follows.

Chapter 2 examines the overall economic contribution of the 'Pharmaceuticals and Related Sector' to the Scottish economy.

Chapter 3 focusses on a more narrowly defined measure of the pharmaceutical sector typically used in the economic literature which allows us to trace changes in employment and activity over time and to assess its performance relative to the UK as a whole.

Chapter 4 looks at the contribution of the sector through the lens of the 'life sciences' definition used by the Scottish Government and discusses the sector's role in delivering the ambitions set out in the Government Economic Strategy.

A key element of the Scottish Government's approach in their Economic Strategy is to develop a more innovative economy. The pharmaceutical sector in Scotland clearly has an important role in this context. Therefore, Chapter 5 examines recent performance in research and development (R&D) with the penultimate chapter discussing some of the opportunities and drivers behind high levels of R&D based upon the experiences from elsewhere.

The report begins however, with a short discussion of the definitions used to describe 'pharmaceuticals' in Scotland.

1.2 Definition of the pharmaceutical sector in Scotland

The pharmaceutical industry in Scotland is an exceptionally broad and dynamic sector.

As a result, a strict definition of activity in the sector is hard to pin down. Gone are the days of the sector comprising firms only working on the development and manufacturing of drugs. Nowadays, other activities from high-valued R&D, sales and marketing, product and client servicing are just as important. At the same time, the lines between sectors, whether that be in university research or bio-technology, are much more blurred.

In this report, we make use of established statistical definitions of the pharmaceutical sector. This necessarily means that the analysis may not fully capture all the activities associated with the sector. Some may be measured elsewhere in the economy. However, we can be confident that the vast majority of activities will be picked up in this analysis.

One added complication however, is that certain definitions used by government – or industry bodies – can differ according to what type of activity is being measured.

In what follows, this study discusses the pharmaceutical industry in Scotland at two levels:

The first is the 'pharmaceutical' industry as defined in the official statistical classification (UK Standard Industrial Classification (SIC)).

'Pharmaceuticals' covers SIC Division 21, and is comprised of two parts[1]:

- 21.1 Manufacture of basic pharmaceutical products; and,
- 21.2 Manufacture of pharmaceutical preparations.

The first element largely comprises the manufacture of medically active substances for medical treatments. The second element comprises the manufacture of actual medical treatments and medical diagnostic preparations.

A limitation of focussing just on this definition is that it largely only covers the *manufacturing* element of the pharmaceutical industry.

Therefore, the report also makes use of a wider definition – the 'Pharmaceuticals and Related Sector' – based upon an approach taken by Scottish Enterprise.

This takes in SIC 21 as above, but covers a wider area of activity including the part of activity in the following three areas that can be readily identified as taking place by the pharmaceutical industry in Scotland:

- computer, electronic and optical products;
- other manufactured goods; and,
- scientific research and development services.

1 See Office for National Statistics UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007).

Case Study - Roche: global company investing in Scotland
As an organisation driven on innovation, Roche relies on a strong research base to deliver advances in treatment for patients across the world. Roche invests heavily in Scotland to help in the delivery of global research efforts. In 2016, Roche spent a total of £132 million in Scotland with NHS Scotland, universities, research organisations and biotechnology companies. Whilst Roche doesn't have any production facilities, it is integral to the success of the Scottish Biotechnology sector. A Memorandum of Understanding with the main NHS Boards in NHS Scotland is focussed on Roche's clinical trial programme. It ensures that Scottish research centres are offered the opportunity to participate in Roche funded trials. Currently this involves 18 hospitals across Scotland participating in 57 clinical trials.

Case Study - GlaxoSmithKline/University of Edinburgh collaboration to treat acute pancreatitis
The UK's biggest medicines and vaccines company, GlaxoSmithKline (GSK), has chosen Edinburgh University for one of a small number of GSK Discovery Partnerships with Academia (DPAc) programmes. Damian Mole, a clinician scientist fellow and consultant surgeon at the University of Edinburgh, has devoted his research efforts to try and unravel the underlying biology causing severe acute pancreatitis. His team identified an inflammatory mechanism in acute pancreatitis associated with the development of multiple organ failure. To develop this idea into a potential medicine, he started a research programme with seed funding from the Health Foundation, the Academy of Medical Sciences, the Medical Research Council and the Wellcome Trust. Under the DPAc agreement terms, the University of Edinburgh has been receiving milestone-based financial support from GSK to support their research, and will receive sales royalties from any medicine that is ultimately commercialised as a result of the collaboration.

Total economic contribution - Pharmaceuticals and Related Sector

Chapter 2

2.1 Background

In this chapter of the report, we provide a summary of our impact analysis of the contribution of the pharmaceutical sector to the Scottish economy[2].

The aim of an economic impact study is to provide a quantitative estimate of the benefits that a particular industry brings to the economy and wider community.

As with other economic impact studies, we make use of industry-specific financial and economic data to estimate the amount of economic activity created across Scotland by the pharmaceutical sector.

As discussed above, in this chapter we use the definition provided by Scottish Enterprise of the 'Pharmaceuticals and Related Sector', which includes not only the manufacture of pharmaceuticals but also other activities, including part of the activity in the following three sectors[3]:

- computer, electronic and optical products;
- other manufactured goods;
- scientific research and development services;

The total economic activity created by the sector's activities can be measured through two avenues.

The first is through the direct impact. This measures the contribution from the actual spend and employment which underpins the pharmaceutical sector's own day-to-day activities.

For example, a number of pharmaceutical companies are major employers in their own right in Scotland – often in parts of the country where employment opportunities are relatively few and far between. These firms will not only employ people but undertake spending on machinery, office space, administration and other activities. All of this helps to create a direct stimulus to the economy that boosts growth in Scotland.

But this only captures part of the story.

The second avenue through which the pharmaceutical sector has an economic impact is through what are referred to as indirect and induced effects.

We know for example, that employees in the sector do not just hold on to their wages and salaries but spend them on goods and services that are produced or distributed by other companies based in Scotland.

At the same time, we know that behind the pharmaceutical sector is a complex supply chain of different businesses across Scotland (and beyond) all of whom will benefit in some way or another from the industry being based here.

Therefore, two further economic effects need to be captured –

- Indirect impacts – the economic benefits from the pharmaceutical sector's suppliers using the revenues from trading with the sector to, in turn, make expenditures on staff and other goods and services; and,
- Induced impacts – the economic benefits from the pharmaceutical sector's employees spending their wages and salaries on goods and services across the Scottish economy.

2 Full details are available on request.

3 See Appendix 1 for a full definition.

These additional impacts, which still stem from the *activities* of the pharmaceutical sector (and would not otherwise have taken place), means that the total amount of economic activity created is greater than simply the initial amount created by the first round of spend by the sector.

To obtain an accurate picture of the sector's total economic impact, it is important to capture these direct, induced and indirect impacts.

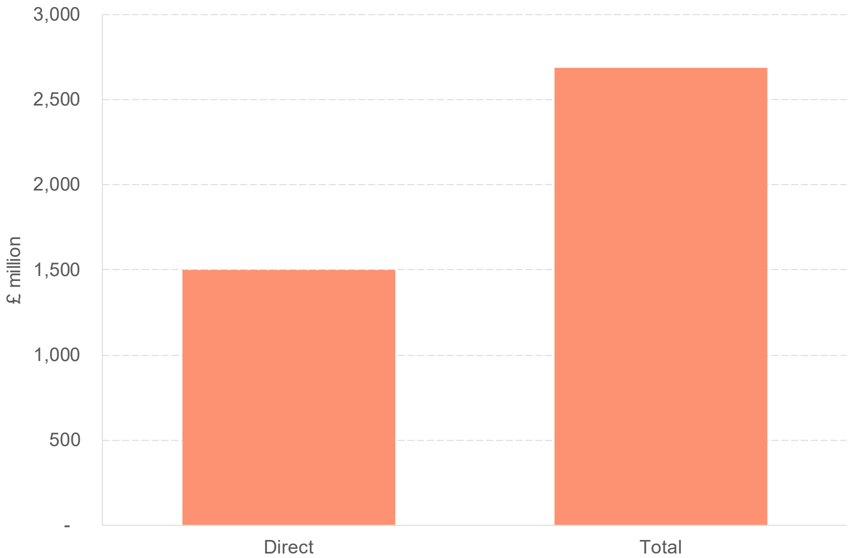
To do this, we make use of economic input-output tables for Scotland.

Economic input-output tables provide a complete picture of the flows of goods and services (products) in the economy for a given year. They detail the relationship between producers and consumers and track the interdependencies of industries. They are constructed from survey and other data sources and provide the most accurate and comprehensive picture of the national economy that is available.

By capturing the complex interlinkages that exist in an economy, these tables can help obtain a picture of the 'multiplier' effects of the pharmaceutical sector's spend and employment on the wider economy and across sectors.

2.2 Output supported

Chart 1: Pharmaceuticals and Related Sector, Scotland, output impacts (£ million)



Source: Fraser of Allander calculations

Chart 1 details our estimates of the direct output[4] of the 'Pharmaceutical and Related' sector in Scotland, and demonstrates that it directly supports £1.5 billion worth of output in Scotland.

As highlighted above, this does not measure the total level of output that the industry supports in Scotland, because it does not take into account the effect that the re–expenditure of the initial spending made by 'Pharmaceutical and Related' companies and their employees.

Therefore Chart 1 also details the total impact on Scottish output once these effects are taken into account.

In total, we estimate that the 'Pharmaceutical and Related' sector supports output worth £2.7 billion across Scotland as a whole.[5]

4 The output produced by an industry in a given time period is a measure of the value of the goods/services it produces in that period. It is estimated as its turnover (sales) plus any changes in inventories of finished goods and work in progress.

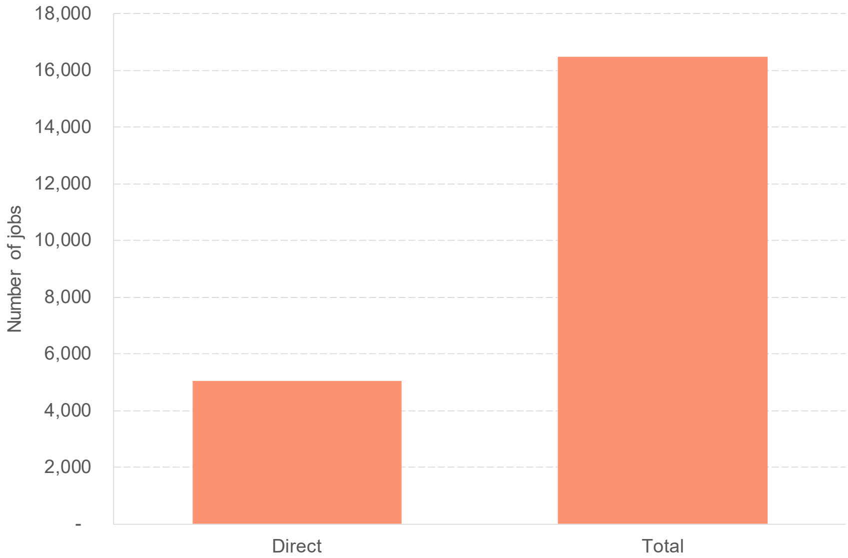
5 Appendix 2 gives a technical explanation of the methods used to derive this estimate.

2.3 Employment supported

Chart 2 demonstrates that the 'Pharmaceutical and Related' sector in Scotland supports around 5,050 direct FTE jobs in Scotland.

A good illustration of the level of growth can be seen by comparing the number of direct FTE jobs estimated here (5,050) with the number of direct jobs in the 'Pharmaceutical and Related' at the time of our last study – when it was estimated to provide 3,100 direct jobs. This is an increase of over 60% since 2009.

Chart 2: Pharmaceuticals and Related Sector, Scotland, employment impacts



Source: Fraser of Allander calculations

Chart 2 also details the estimated total employment impact of the 'Pharmaceutical and Related' sector, and shows that while the industry directly provides an estimated 5,050 FTE jobs, it supports a total of around 16,500 FTE jobs in Scotland once the re-expenditure impacts, arising from wage and supplier spending explained above are taken into account.

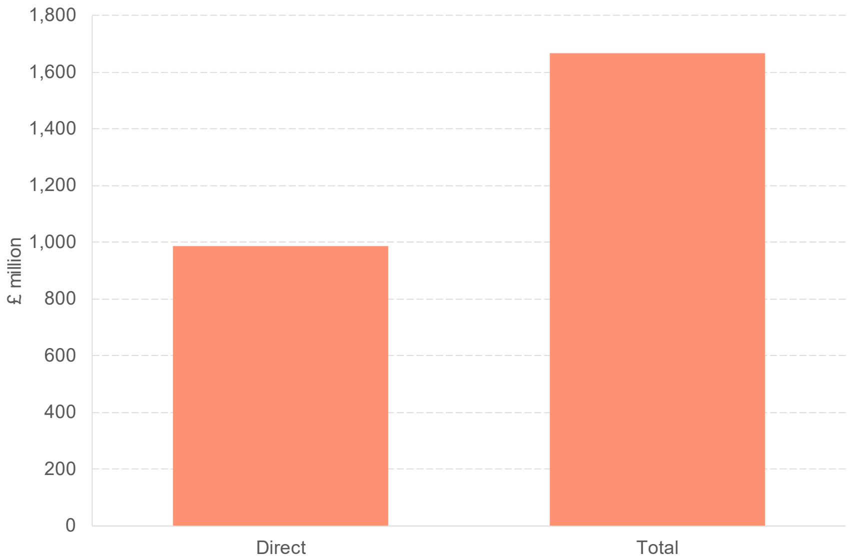
This means that for every employee in the 'Pharmaceutical and Related' sector an additional 2.27 jobs are supported elsewhere in the Scottish economy. This figure of 2.27 is similar to the additional employment created per employee in our previous study[6].

6 Back in 2009 we estimated that every employee in the 'Pharmaceutical and Related' sector supported an additional 2.25 jobs, and a total of 10,089 supported jobs.

Additional activity supported in the pharmaceutical sector
As discussed above, one of the key challenges in assessing the economic contribution of a sector such as pharmaceuticals is that the formal statistical definitions that measure the scale and size of the sector may not always fully capture all the activity taking place in the sector. For example, there are a significant number of field-based pharmaceutical employees throughout Scotland who are not captured in official figures. These roles will mostly be in commercial sales or in clinical research and are usually home based jobs. However, in many instances, these jobs are registered to company head offices, normally in England. ABPI Scotland have provided the FAI with an estimate of the number of field-based employees, using data from a survey of 17 of their member companies. The responses included many large global pharmaceutical companies who operate in Scotland. The survey returns showed that these 17 companies employed a total of 339 field-based people in Scotland. Given ABPI total membership stands at 60 full member companies (at the time of writing), a conservative estimate of the total field-based pharmaceutical employment across the ABPI member companies in Scotland would be in excess of 500. Using the Scottish Government's pharmaceutical industry employment multiplier, we estimate that this field-based pharmaceutical employment would support at least a further 1,000 – direct, indirect and induced – jobs across the Scottish economy.

2.4 GVA supported

Chart 3: Pharmaceuticals and Related Sector, Scotland, GVA impacts (£ million)



Source: Fraser of Allander calculations

The most widely-used measure of economic activity is Gross Value Added (GVA), which assesses the increase in economic value provided by an industry[7].

Chart 3 details our estimate of the total GVA supported in Scotland by the 'Pharmaceutical and Related' sector. It illustrates that the level of direct GVA created by the sector is estimated at £0.99 billion.

This is estimated to support a total of £1.7 billion across all industries in Scotland once the wider spill-over effects are taken into consideration.

7 For any industry, GVA measures the increase in economic value provided by that industry in a given time period (typically a year). GVA is defined as the total value of goods and services produced by an industry, after deducting the cost of goods and services used in the process of production. It therefore measures what the industry itself *adds* to the value of an economy.

Recent developments in the pharmaceutical sector in Scotland

Chapter 3

3.1 Introduction

In this chapter, we examine recent changes in the pharmaceutical sector in Scotland.

To enable comparisons over time and to allow for analysis of activities within Scotland and relative to the UK as a whole, it is necessary to focus on the more narrowly-defined 'pharmaceutical' sector covered under the Standard Industrial Classification (SIC) 21.

This more narrow definition is because the definition used in Chapter 2 – whilst entirely appropriate – has been created by Scottish Enterprise to enable a richer picture of the sector to be established. But to enable usage of key economic and business databases a slightly narrower approach is required that follows standard national accounts practice.

It should be noted however, that – measured by output – the SIC 21 category comprises the vast majority (88%) of the direct activity produced by all the 'Pharmaceutical and Related' activity utilised in Chapter 2. We can be confident therefore that this still provides a useful assessment of the sector's recent performance, particularly in tracking its progress over time and relative to other parts of the UK.

Table 1 shows the number of people employed in the pharmaceutical industry in Scotland according to this definition.

Total Scottish employment in pharmaceuticals during 2015 was 3,175 - the most recent year data is available.

Table 1: Pharmaceutical employment, Scotland, 2009 to 2015

Year	Employment
2009	2,200
2010	3,000
2011	3,600
2012	3,300
2013	3,100
2014	3,200
2015	3,175

Source: Scottish Government Growth Sectors database

Employment in the sector has grown strongly in recent years – with total direct employment up 38% since 2009.

A key goal of the Scottish Government is supporting economic growth across the length and breadth of Scotland. In particular, they seek to ensure that the prosperity created by economic growth is shared across the country through a fair and inclusive jobs market.

It is interesting to note that the largest concentrations of pharmaceutical employment in Scotland are in Highland and North Ayrshire – where pharmaceutical jobs account for around a quarter and a third of all such industry jobs in Scotland, respectively[8].

8 Source National Online Manpower Information Services (NOMIS).

The regional employment picture is therefore particularly important when viewed through the lens of inclusive growth. In North Ayrshire for example, the sector is estimated to support 431 direct employees in the local authority. This is equivalent to just over 1 in every 100 local jobs.

These jobs are vital. In North Ayrshire, the local unemployment rate in March 2017 was 8.1%, considerably above the Scottish average rate of 4.5%.

3.2 Links to other sectors – what other sectors of the economy benefit from pharmaceuticals in Scotland?

As discussed above, the reach of the pharmaceutical industry in Scotland is not just limited to the sector itself. It forms an important end-point for a complex supply chain across the Scottish economy with many businesses – some closely related to the sector, some less so – all benefiting from having both a major employer and investor located in Scotland.

Table 2 below shows the links between the pharmaceutical sector and other industries in Scotland by identifying the parts of the economy which receive some direct benefit from the spending of the pharmaceuticals industry[9].

The key industry supported is pharmaceuticals itself, which is estimated to receive 27% of all supplier spending. In others words, nearly 30% of spending by the sector is to other firms in the sector.

It is worth noting here that this proportion has increased from our previous study, where the proportion was around 16%. This suggests that pharmaceutical companies in Scotland have improved their local supply base in recent years.

Other significant sectors supported include wholesale (around 10% of all spending) and financial services (6%).

As the table highlights, the sector helps support activity right across the Scottish economy from computer services through to employment services.

Case Study - Bristol-Myers Squibb (BMS): Global pharma investing in research collaboration with Midlothian based pharma services company
The BMS R&D site at Moreton, Merseyside, has a Pharmaceutical Materials Science Group, which works closely with medicine substance manufacturing sites across Europe. One aspect of this work is research relating to the "solid state" of the medicine substance. Since 2011, BMS and Midlothian based Solid Form Solutions have successfully collaborated on a number of projects to advance and understand BMS' products in the pipeline. This collaboration, which has already seen a six-figure investment, is expected to expand in the years to come. This research makes a key contribution to the understanding of stability and effectiveness of a medicine, and is an important component of the regulatory package and the intellectual property around a new medicine. Solid Form Solutions is based in laboratory facilities near Penicuik, and the collaboration is an example of the benefits of investment and collaboration by a global bio-pharmaceutical company, that has knock-on effects to the wider life sciences sector in Scotland.

9 The analysis here uses the Input Output tables published by the Scottish Government which provide detailed data for 97 industrial sectors in Scotland.

Table 2: Main industrial purchases made by pharmaceuticals in Scotland, 2013

Sector	% purchases
Pharmaceuticals	27.3
Wholesale - excl. vehicles	10.4
Financial services	5.7
Architectural services	4.1
Post and courier	3.6
Rubber and Plastic	3.4
Fabricated metal	3.3
Wholesale and Retail - vehicles	2.6
Electricity	2.5
Paper and paper products	2.3
Accounting services	2.3
Transport support	2.0
Other	30.6

Source: Scottish Government Input-Output tables, 2013

3.3 Output, export and productivity performance

It is possible to examine the relative change in economic output over recent years. The most recent Scottish Input-Output tables show that the pharmaceutical sector has grown by around 28% between 2008 and 2013. To put this in context, [over the same period] output in manufacturing has fallen by around 10%.

At the centre of the Scottish Government's Economic Strategy is the goal of boosting exports and productivity.

The strong performance – and potential – of the pharmaceutical industry in Scotland to contribute to both of these objectives is one of the key reasons that they have been identified as part of the life sciences Growth Sector.

Using the most recent Scottish Government data, it is estimated that total pharmaceutical exports increased by 26.7% between 2008 and 2013[10]. International exports by pharmaceuticals increased by almost a fifth (19%) over the period

This is faster than the equivalent figure for Scottish exports in general where growth was around 15%.

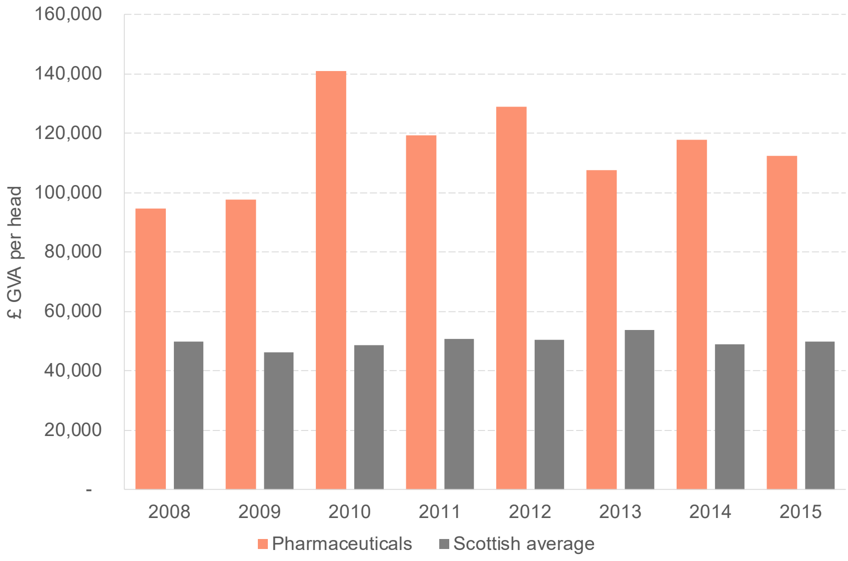
The productivity of the sector is a key strength. Chart 4 compares GVA per employee for the pharmaceuticals sector against productivity in Scotland as a whole[11].

Whilst volatile, productivity in the pharmaceutical sector has risen by around 19% between 2008 and 2015. The relative growth in the sector was also faster than the Scottish average.

10 Total exports includes the sector's exports to both the Rest of the UK (RUK) and the Rest of the World (ROW).

11 Note the Annual Business Survey excludes the financial sector and parts of agriculture and the public sector.

Chart 4: Productivity – measured by GVA per head – pharmaceuticals and Scottish average, 2008 to 2015



Source: Annual Business Statistics (ABS)

Gross wages and salaries per head in 2015 were £36,682. This is around £15,000 higher than the Scottish average.

3.4 Performance relative to the rest of the UK

We next examine comparable statistics from the UK Office for National Statistics to assess the Scottish sector's performance relative to the UK as a whole.

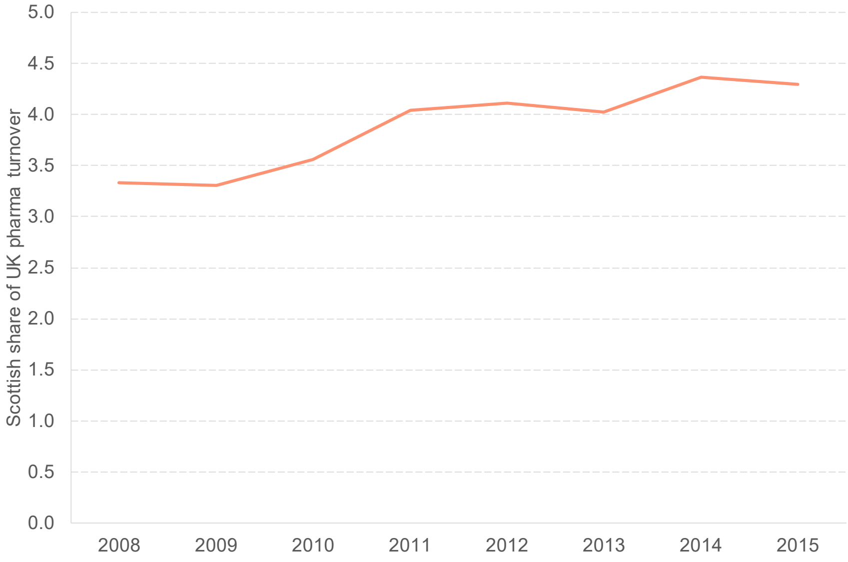
Overall the data reveals that Scotland has been doing relatively well in comparison to the UK. Turnover figures for the UK and Scotland (Chart 5) shows that the industry in Scotland currently represents 4.3% of all UK sales (in 2015).

This percentage has risen from 3.3% in 2008, an increase of 1 percentage point in seven years.

As detailed in Chart 6, the increased percentage of UK turnover in Scotland has also been reflected in terms of employment shares, with the data demonstrating that the industry in Scotland has accounted for an increasing proportion of UK jobs since 2008[12] - that is, 9.3% in 2015 up from 5.1% in 2008.

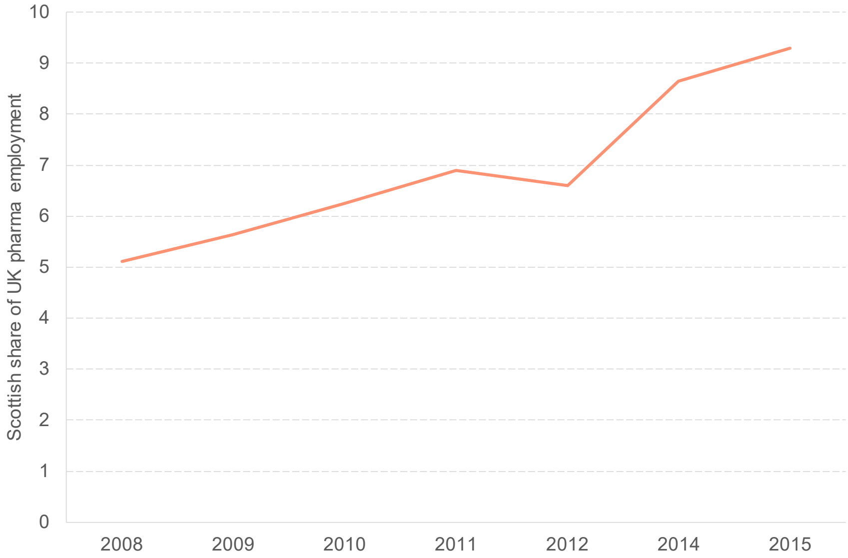
12 UK employment figures for 2013 was disclosive.

Chart 5: Pharmaceutical turnover, % of UK total in Scotland, 2008 to 2015



Source: Annual Business Statistics

Chart 6: Employment, % of UK total in Scotland, 2008 to 2015



Source: Annual Business Statistics

The pharmaceutical industry's contribution to Scottish life sciences

Chapter 4

4.1 Introduction

The purpose of the Scottish Government is to deliver faster sustainable economic growth with opportunities for all to flourish. By developing a more productive and successful economy, the aim is to boost prosperity for the population as a whole and to ensure that more people have an opportunity to benefit from economic growth.

The Scottish Government's Economic Strategy has two 'mutually supportive goals' of increasing competitiveness and tackling inequality.

Underpinning the Government Economic Strategy are four key drivers that the Scottish Government believes will shape both the pace and type of growth in Scotland in the years ahead.

These are – *inclusive growth, investment, internationalisation and innovation.*

The pharmaceutical industry makes an important contribution to all four of these drivers.

On *inclusive growth,* as highlighted above the sector employs significant numbers of people in areas of the country where employment opportunities have traditionally been more limited.

On *internationalisation,* the sector is a major exporter and – as the case studies have documented – the sector is also securing significant new *investment* into Scotland.

Finally, as we will discuss in detail in Chapter 6, the industry is at the forefront of developing a more *innovative* economy through its research and development activities.

The importance of economic growth is all the more vital given the new fiscal powers of the Scottish Parliament. Soon, around half of Holyrood's annual resource budget will depend upon the revenues that are raised in Scotland.

4.2 Scottish Government Economic Strategy and Growth Sectors

A key avenue through which the Scottish Government intends to deliver on its Economic Strategy is through their targeted support toward areas where Scotland has a distinct international comparative advantage.

Accordingly, the Scottish Government has identified six Growth Sectors where it believes Scotland has economic strengths:

- Food and Drink
- Financial and Business Services,
- Life Sciences
- Energy
- Tourism
- Creative Industries

The Scottish Government's recent 'Life Sciences Strategy for Scotland: 2025 Vision'[13] estimated that life sciences contributes £4.2 billion of turnover to the Scottish economy. The aim is to grow this to £8 billion by 2025.

Table 3 details employment in the life sciences sector in Scotland for the latest year for which figures are available (2015).

Table 3: Growth Sector employment Scotland, 2015

Sector	Employment
Food and Drink	114,700
Financial and Business Services	217,400
Life Sciences	17,300
Energy (including Renewables)	73,000
Sustainable Tourism (Tourism related Industries)	217,000
Creative Industries (including Digital)	73,600

Source: Scottish Government Growth Sectors database

Given the status of these industries as economic priority sectors, it is also interesting to examine their employment performance in recent years – particularly in the aftermath of the Great Recession.

Table 4: Growth Sector employment change, Scotland, 2009 to 2015[14]

Sector	Employment change (%)
Food and Drink	0
Financial and Business Services	- 6.2
Life Sciences	24.5
Energy (including Renewables)	18.9
Sustainable Tourism (Tourism related Industries)	13.8
Creative Industries (including Digital)	3.6
All Scotland	0.7

Source: Scottish Government Growth Sectors database

Between 2009 and 2015, total employment in Scotland grew by just 0.7%. Employment growth across all six Growth Sectors (i.e., those identified in Table 4) was 3.6%.

Overall, conditions have therefore remained challenging in the Scottish economy since 2009. For example, and as Table 4 highlights growth in two of Scotland's largest Growth Sectors – food and drink and financial and business services – has been particularly weak.

In contrast, employment in life sciences – of which pharmaceuticals is a key part – has increased substantially. In the overall Growth Sector 'life sciences', the number of people employed has risen by almost a quarter (24.5%) since 2009.

Table 5 details the relative employment performance of sub-sectors within life sciences.

13 Life Sciences, Strategy for Scotland, 2025 Vision - http://www.lifesciencesscotland.com/wp-content/uploads/2017/08/Life-Sciences-Strategy-for-Scotland-2025-VisionFINALlow-res.pdf

14 The 'All Scotland' figure is for employment change across all industrial sectors in Scotland, not just the key growth sectors.

Two of the sub-sectors that involve the manufacture of medical devices have decreased. Conversely employment in *'Basic pharmaceutical products and pharmaceutical preparations'* has increased.

Table 5: Life sciences employment change Scotland, 2009 to 2015

Sector	% change
Basic pharmaceutical products and pharmaceutical preparations	45.5
Manufacture of irradiation, electromedical and electrotherapeutic equipment	-50.0
Manufacture of medical and dental instruments and supplies	-25.0
Research and experimental development on biotechnology	133.3
Other R&D (natural sciences and engineering)	39.5

Source: Scottish Government Growth Sectors database

In 2015, pharmaceuticals contributed 20% of all life sciences employment, compared to just 16% in 2009.

4.3 Summary

Overall, the last two chapters have documented the recent performance of the pharmaceutical sector in Scotland.

As Chapter 3 outlined, in terms of the relatively narrowly defined 'pharmaceutical' sector, growth has been relatively strong, with both employment growing and Scotland's share of overall UK economic aggregates also increasing.

And in Chapter 4, we also see that the sector is a growing as part of the life sciences sector in the Scottish economy. Indeed, the most recent data suggests that a large part of the relative success of the life sciences Growth Sector has been the performance of the pharmaceutical industry.

Research and development activity in pharmaceuticals in Scotland[15]

Chapter 5

5.1 Introduction

In this penultimate part of the report, we examine in a little more detail, recent developments in R&D activity within the pharmaceutical sector.

Increasing research and development is a key aspect of the Scottish Government's growth strategy. Indeed, the First Minister recently outlined her vision for Scotland's future economic prosperity to be shaped by Scotland taking advantage of new innovations and technological change[16].

5.2 R&D activity

Unfortunately, the most recent data on actual R&D *spend* in Scotland sheds little light on recent activity.

This is because data for the most recent years – 2013 and 2014 – have been deemed disclosive by Scottish Government statisticians. The data is therefore not available to be published. The most recent figures are for 2012 and are therefore now five years out of date. These figures did show that spending was down around 25% in real terms (i.e. adjusted for inflation) on its 2007 level.

One explanation for this could be an increase in pharmaceutical companies contracting out their R&D spending. It is not possible to establish this conclusively on the basis of the available data, but as we discuss below other indirect evidence of activity points to a somewhat healthier picture[17].

More up-to-date information is available on R&D employment in the sector covering up to 2015. These show a fall in the number of people employed in R&D compared to a decade ago, although the figure has stabilised (albeit at a lower level) since 2011 – Chart 7.

5.3 Other R&D analysis - Scottish Enterprise data

The data on R&D activity in Scotland is therefore patchy. Indeed one key improvement that is needed – particularly given the importance of the sector in Scotland – is a more comprehensive databank of such activities to enable policymakers to keep a more detailed eye on progress.

Scottish Enterprise do maintain their own database which provides additional figures on two sectors that relate – in part – to the level of R&D undertaken in the sector:

- ***Pharmaceutical Services and Contract Research*** – These are companies providing services to pharmaceutical companies, which include Contract Manufacturing Organisations (CMOs), Contract Research Organization (CROs) and specialised consultants. CMOs provide services to other companies in the pharmaceutical industry on a contract basis, including drug development. CROs also provide services to the pharmaceutical industry, including outsourced research services.
- ***Professional Services*** – These are companies which provide – *at least in part – dedicated support to pharmaceutical firms*. These could include specialised intellectual property lawyers.

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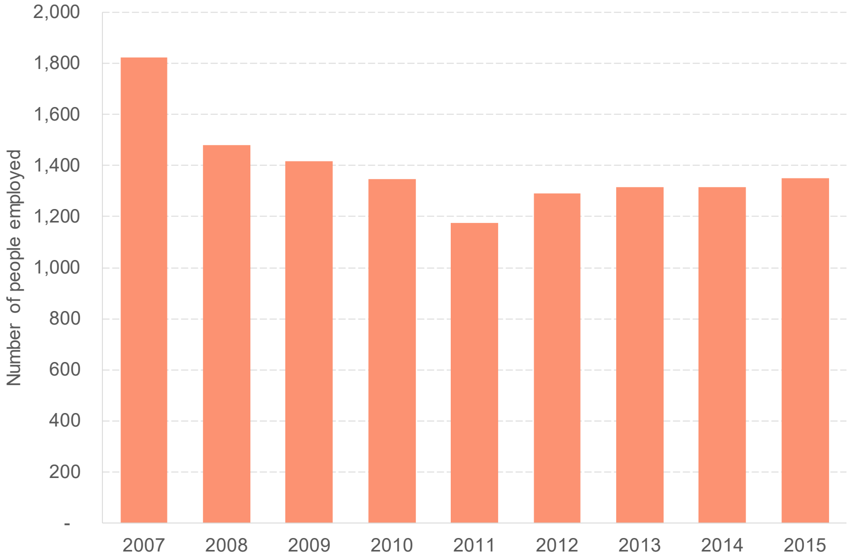
15 See Appendix 1 for a discussion of the figures used in this chapter.

16 https://firstminister.gov.scot/programme-for-government-2017/

17 See figures from the Industry Partnership Forum discussed below.

The Scottish Enterprise data records that the 'Pharmaceutical Services and Contract Research' sector directly employed 5,000 people in Scotland in 2014.[18] It should be noted that this is, therefore, a much broader definition than is included in the SIC classification of pharmaceuticals. It should therefore be used with caution.

Chart 7: R&D employment in pharmaceuticals in Scotland, 2007 to 2015



Source: Figures supplied by Scottish Government

The Scottish Enterprise figures also detail change in employment in the sector since 2008, and estimate that the number of jobs increased by 800.

This increase in the number of jobs was matched by an increase in the number of companies operating in this sector in Scotland, which Scottish Enterprise estimate increased from 95 to 117.

For the second of these – the professional services companies supporting pharmaceuticals – employment increased from 800 to 1,000 between 2008 and 2014. The number of companies operating also rose, from 67 to 72.

Because they employ different industrial categorisations, it is not possible to match the Scottish Enterprise figures with the Standard Industrial Classification figures discussed above.

But it is worth noting that the growth in both 'Pharmaceutical Services and Contract Research' and 'Professional Services' companies serving pharmaceuticals does contrast with the fall in R&D employment witnessed in the official statistics. This could – in part – be a result of increased outsourcing by pharmaceutical companies but this requires further investigation.

18 These employees are not included within the Standard Industrial Classification (SIC) definition of the 'Pharmaceutical' sector used above.

Case Study – MSD: US pharma company investing in Scottish R&D
IOmet Pharma Ltd, a privately-held drug discovery company based in Edinburgh became a wholly owned subsidiary of MSD in January 2016. IOmet are based at the Edinburgh BioQuarter, one of Scotland's life science clusters of excellence, and their acquisition by MSD (known as Merck & Co in the USA and Canada) represented a major vote of confidence in the Scottish life sciences sector. The focus of their business is in the field of cancer immunotherapy, a way of harnessing the power of the body's own immune system to treat cancer. The commercial terms of the deal were not disclosed by either party, but have been widely reported in the media as being worth up to £280m, depending upon the achievement of commercial milestones. This represents a huge investment in Scotland by a global pharmaceutical company, and highlights the emerging pattern of foreign investment likely to become more common in the future. According to Scottish Enterprise around £30m was invested elsewhere in the life sciences sector in Scotland in 2016, which highlights the significance of this investment by MSD.

5.4 Other R&D analysis – NHS Research Scotland figures

NHS Research Scotland is a partnership of Scottish NHS Boards and the Scottish Government's Chief Scientist Office (CSO). They work to create a research environment that can attract R&D investment (such as clinical trials) from global pharmaceutical companies.

Data provided by NHS Research Scotland demonstrates that both the volume and value of trials and research undertaken in Scotland funded by major pharmaceutical companies has grown in recent years.

Table 6 highlights the rise in the number of studies, which grew by over 50% in a 5-year period and which increased year on year (other than 2014/15)[19].

Table 6: Number of IPF-approved clinical studies, NHS Scotland 2011/12 to 2016/17

Year	Number of studies
2011/12	200
2012/13	275
2013/14	328
2014/15	272
2015/16	303
2016/17	309

Source: NHS Research Scotland

This increased volume of research has also meant that the amount spent by pharmaceutical companies on trials and research has increased.

Table 7 highlights that spending on commercial trials and research increased by 63%, a higher rate of growth than in the number of clinical studies[20].

This suggests that Scotland is not only attracting more clinical trials but also more *valuable* clinical trials.

19 Number of new studies awarded NHS Management approval.

20 Value of new site contracts awarded NHS permission.

Table 7: Value of commercial research and clinical trial spending, Scotland (£ million) 2011/12 to 2016/17

Year	Contract value
2011/12	11.8
2012/13	14.3
2013/14	18.4
2014/15	16.3
2015/16	18.7
2016/17	19.8

Source: NHS Research Scotland

The majority of the spending shown in Table 7 was in NHS Greater Glasgow and Clyde, NHS Lothian and NHS Tayside and covered 8 different clinical therapy areas[21]. The data also shows the majority of research funding, an estimated 75%, of contract spending was used for personnel costs and so was used directly to recruit and retain qualified research and medical staff.

5.5 Summary

As the analysis above highlights, the data on R&D activity in the pharmaceutical sector within Scotland is mixed.

On the one hand, the official statistics appear to show a decline in R&D activity, although this has stabilised somewhat in recent times.

In contrast, other data – both from Scottish Enterprise and NHS Scotland – provides some more positive results. With increased activity in the sectors that support R&D activity and a rise in the number and value of studies going to clinical trials, then this suggests a more healthy level of R&D activity than the official figures would appear to demonstrate.

In the final chapter, we consider some lessons that can be taken from the experience elsewhere of what might be done to attract greater levels of R&D activity to Scotland.

21 Cancer, Cardiovascular, Dementia, Diabetes, Gastroenterology, Inflammation, Neurology and Respiratory issues.

Attracting international research and development investment

Chapter 6

6.1 Introduction

Research & Development (R&D) units, where company subsidiaries conduct research on behalf of the parent company, bring substantial investment to the areas in which such activity takes place.

They also typically involve highly paid research jobs.

The proximity of R&D facilities may also involve spill-over benefits to other local firms, further enhancing the local economy.

Given this, many countries aspire to attract international R&D investment.

Interest in this area has spawned a considerable literature which has tried to identify the factors that attract these investments to certain locations.

This section of the report reviews some of the main findings of this literature.

The importance of boosting R&D activity should not be underestimated. For example, a recent report commissioned by Pfizer[22] examined the potential economic benefits that might arise from closing the UK's 'patient access gap'.

It was estimated that – under a scenario of improving patients' access to medicines – the additional boost to UK R&D activity could be in the region of 1,900 new jobs. Applying such an analysis to our modelling here, we estimate that the equivalent figure for Scotland would be 224 jobs and GVA of £23 million.

Case Study – Pfizer: A major research collaboration between global pharma and NHSScotland
In 2013, Scotland became the only entire country in the world to be awarded with Pfizer global INSPIRE status. INSPIRE sites are part of Pfizer's international network of preferred locations for clinical research, helping to bring innovative medicines to patients in Scotland and around the world. There are currently over 90 Pfizer INSPIRE sites across the world, but Scotland is the only entire country. Pfizer, a US pharma company, chose Scotland because it offers and ideal mix of some of the best health data in the world, a collaborative approach to research, high incidence of some diseases and efficient support for study start-ups provided by NHS Research Scotland. INSPIRE sites are identified as highly productive and effective in conducting clinical trials; meet strict criteria including running trials to the highest standards within set timelines; ensuring dedicated, high-quality staff and resources; and expertise in key disease areas targeted by Pfizer's R&D pipeline. Under this programme, Pfizer and NHSScotland health boards will share expert knowledge and experience in research to help bring new medicines to patients in Scotland, the UK and around the world, the partners said. Clinical trials represent a multi-million investment in Scotland's clinical research sector; in 2016/17 the combined value of active studies to Scotland was £36.8m* (NHS Research Scotland).

22 See - www.pfizer.co.uk/latest-news/2017-07-25-driving-global-competitiveness-uks-life-sciences-ecosystem

6.2 Market size

There is empirical evidence to indicate that market size is a major determinant of where multinational enterprises (MNEs) choose to locate international R&D facilities.

While R&D facilities may be standalone units within a company, market size is important because R&D units have in many cases evolved from the company's initial role as a production facility. While internationally-owned facilities may typically begin as production units, many evolve over time and increase the number of higher-value activities they undertake.

Many firms, for example, have marketing departments attached to production units to target sales for overseas markets. Particularly in high-technology industries, lower-level R&D might also be sited alongside manufacturing units in situations where products need technological adaptations for overseas consumers and/or regulators.

In some cases, these may in turn lead to subsidiaries developing specialized capabilities to help firms compete. R&D often, therefore, follows production, and market size, especially in high income and high income growth areas, and is an important driver for international R&D investment.

Evidence for this is cited in a number of publications (e.g. Birkinshaw and Hood[23], who note that overseas R&D activities are, in most cases, an extension of existing overseas production and marketing activities).

Head and Mayer's study of Japanese FDI in Europe[24] also found that producers concentrate where demand is highest. They cite Toyota's decision to build a car plant in France, despite already having production facilities in the UK and quote the then chairman of Toyota as saying *"We want to build our plants where the markets are"*[25].

Blongen's 2005 review of Foreign Direct Investment[26] (FDI) further confirms the importance of market size.

All of this makes Brexit – particularly around collaboration and the regulatory environment – an important consideration for the industry in the years to come.

6.3 Skills and education systems

For standalone R&D units (which may not be attached to other parts of the foreign subsidiary) another attraction factor is the quality of local education systems and the skills level of the workforce.

Given the scientific capabilities necessary, particularly for higher level R&D, companies will clearly require qualified personnel, typically to at least graduate level. Research by Lewin *et al*[27] demonstrated that a sufficient supply of skilled employees is a necessary condition for attracting foreign R&D. Research by the European Commission (2010)[28] has also found that the availability of researchers is one of the four main factors attracting foreign R&D investment among European multinationals.

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23 This process is described in, for example, Birkinshaw, J.M., and N. Hood (1998), "Multinational Subsidiary Evolution: Capability and Charter Change in Foreign- Owned Subsidiary Companies", Academy of Management Review 23(4), pp. 773-795.

24 Head, K and Mayer, T, (2004) "Market potential and the location of Japanese Investment in the European Union" Review of Economics and Statistics, 86(4):959-972.

25 Page 959.

26 Blonigen, B (2005), "A Review of the Empirical Literature on FDI Determinants", National Bureau of Economic Research, Working Paper No. 11299.

27 "Why are companies' offshoring innovation? The emerging global race for talent". Lewin, Massini and Peeters, Journal of International Business Studies (2009), pp 901–925.

28 European Commission JRC-IPTS: "The main drivers for the internationalisation of R&D activities by EU MNEs", IRMA Working Paper on Corporate R&D and Innovation 2/2010, EUR 24325 EN/2.

There is also some evidence that large international firms are increasingly able to outsource higher-value functions, including R&D, either to its own subsidiaries or to external companies[29].

Various factors are argued to be behind this trend, including improved information technologies and the increasing ability of companies to modularize even complex business processes, including research and innovation.

Results for US companies show that greater offshoring of product development has arisen from a shortage of high-skilled science and engineering talent in the USA and that these companies have increasingly addressed this by accessing these skills globally.

Case Study – World's longest running collaboration between pharma and academia
The University of Dundee's Division of Signal Transduction Therapy (DSTT) was awarded funding of £7.2m in 2016 by international pharmaceutical companies Boehringer Ingelheim, GlaxoSmithKline and Merck, continuing a partnership that will soon celebrate its 20th anniversary. The funding secures the posts of 38 scientists for four years, and will enable the DSTT to continue its research into a number of disease areas, including cancer, arthritis, lupus, hypertension and Parkinson's. It works to help identify new medicine targets and then accelerate the early phase development of improved treatments. The DSTT is made up of 22 research teams. Founded in 1998, it is now the longest running collaboration between academic research laboratories and the pharmaceutical industry anywhere in the world. It was awarded the Queen's Anniversary Prize for Higher Education in 2006, in recognition of its success in bringing academia and the pharma industry together so productively. Since 1998, the DSTT has attracted £58m in funding. On securing this latest round of investment, DSTT Director, Professor Dario Alessi, said: "The DSTT collaboration provides a unique platform through which our Dundee investigators and pharmaceutical companies can work together…"

6.4 Research quality, local knowledge and "tacit" knowledge

While the quality of graduate output is acknowledged as having an effect on the decision to undertake R&D in a particular location, this is most likely to be an enabling factor and another university output, the quality of the local knowledge base, is probably of greater importance.

The studies cited above suggest that the availability of qualified labour is to some extent a "push" factor; firms are forced to undertake R&D abroad because of the lack of a sufficient supply of highly-skilled labour in the home country.

In contrast, where specialised scientific knowledge is concentrated in centres of excellence, this is a significant "pull" factor drawing foreign R&D units to locate there.

The European Commission study cited above judged that access to specialised knowledge was the most important factor underlying foreign firms' decisions to locate R&D facilities abroad. This points to the importance of the quality of university research as a key driver of foreign R&D.

Belderbos et al[30] analysed the R&D decisions of 176 leading European, US and Japanese firms in 40 host countries and found that these firms' propensity to undertake foreign-based R&D was strongly related to

29 See Lewin, Massini and Peeters (2009).

30 Belderbos, R., B. Leten, and S. Suzuki (2009), Does Excellence in Scientific Research attract foreign R&D? UNU-Merit Working Paper, UNU-MERIT, Maastricht.

the strength of local academic research (as measured by the number of publications in scientific journals).

The impact of academic research was also more significant where the firms themselves had a strong scientific orientation (in industries such as pharmaceuticals or chemicals, for example).

Hedge and Hicks[31] also demonstrated that the innovation activities of overseas US subsidiaries are related to the scientific and engineering capabilities of the host countries. Their study found a relationship between the amount of foreign R&D undertaken and the technological strength of the foreign country (as measured by the number of patents registered).

Case Study - Bristol-Myers Squibb (BMS) - Investing in the University of Strathclyde, and highlighting how global pharma companies collaborate with Scottish universities
BMS is part of the ADDoPT (Advanced Digital Design of Pharmaceutical Products) project, a £20 million programme funded by the Advances Manufacturing Supply Chain Initiative (AMSCI). ADDoPT aims to develop world-class modelling capabilities to the pharmaceutical industry and its regulators, for all aspects of pharmaceutical development. A central part of this programme is the collaboration with the Institute of Pharmacy and Biomedical Sciences at the University of Strathclyde, who have world-leading capabilities in understanding the solid state crystal form of medicines. Professor Alastair Florence is leading a key part of the modelling, and providing understanding of the outputs, the pharmaceutical compounds and real world therapeutic medicines. Other collaborations between BMS and Professor Florence are expected to follow, highlighting the way in which research collaborations with Scottish universities can attract global bio-pharmaceutical company investment, and government funding.

In terms of foreign R&D investment in science-based sectors, an important consideration is the extent to which the knowledge which attracts companies is “tacit”. The type of newly-developed knowledge used in new products is typically both uncertain and intangible.

The importance of the local knowledge base comes out very strongly in a study by Abramovsky *et al*[32], the most extensive study of R&D location in the UK.

The authors explored the relationship between the location of company R&D labs and university research departments for a total of 10,492 research establishments in Great Britain (including 158 pharmaceutical establishments). The research used data (at R&D-unit level) on the amount of company R&D activity, and related changes in this to changes in the location of research quality, using figures from the UK Government’s Research Assessment Exercise (RAE).

They found that presence of, and change in, private sector R&D was closely related to RAE results. Interestingly, the strongest evidence for co-location of companies and university research was in pharmaceuticals, where R&D units were most likely to be located near to university research, particularly where the departments were 5 or 5* RAE rated.

While its main focus was on the pull of highly-rated scientific establishments, the study also allowed for a number of other factors and so also assessed their relative importance compared to local R&D expertise. These included the skill composition of the local workforce (measured by the proportion of the local workforce employed as scientific and technical professionals), the number of science parks in each area and the labour

31 Hedge, D., and D. Hicks (2008), “The maturation of global corporate R&D: Evidence from the activity of U.S. foreign subsidiaries”, Research Policy 37(3), pp. 390–406

32 Abramovsky, L, Harrison, R and Simpson, H, “University research and the location of business R&D”, The Economic Journal, March (2007), pages 114-141.

market contribution of local universities (measured by the number of research students living locally). As noted, research quality was measured by RAE results.

University ratings had a positive effect on R&D location decisions as did the presence of science parks, but neither explained R&D location to the same extent as the availability of local research expertise. In relation to pharmaceuticals, the authors concluded that *"it is the presence of relevant departments… that is most associated with the location of R&D establishments"*[33].

Case Study – AstraZeneca – Cutting-edge collaborative research in Scotland
AstraZeneca, a global pharmaceutical company with a major UK presence, is partnering with Stratified Medicines Scotland Innovation Centre (SMS-IC) on a range of collaborative initiatives. This work is part of AstraZeneca's Integrated Genomics Initiative, which will leverage information from up to two million genomic sequences over 10 years. The goal is to identify rare genetic variations that are associated with disease and how different individuals respond to treatment. SMS-IC is the strategic initiative that brings together and facilitates interactions between healthcare, life sciences and academic organisations to deliver precision medicine programmes effectively and efficiently. It provides access for industry partners, like AstraZeneca, to a host of high-quality data assets and associated services. It also provides direct access to a network of world-class clinical and academic institutions working at the leading edge of precision medicine research and real world application. Commenting on the collaboration, Professor Dame Anna Dominiczak (Vice Principal and Head of the College of Medical, Veterinary and Life Sciences at the University of Glasgow) said: "I am delighted that AstraZeneca has chosen Scotland to partner with in this ground-breaking genomic and informatics venture. I believe that through this new partnership we as a university, alongside all other Scottish partners, will be able to further develop this important area of medical research" AstraZeneca's Executive Vice President IMED Biotech Unit and Global Business Development, Mene Pangalos said: "Working together with NHS Scotland, Scottish universities and Stratified Medicine Scotland will be a really important part of our strategy. This collaboration will provide access to consented genomic samples, electronic health records and importantly the ability to recall patients for deeper clinical investigation to help us better understand the underlying causes of disease"

6.5 Links between policymaking in industry and health care

Finally, it is also argued that the importance of close working between policymakers and industry is crucial to the setting up of international R&D activities. This is, for example, seen as one of the key reasons behind the success of Belgium as a location for R&D activity in the EU.

In Scotland, the Scottish Government works with the life sciences sector in a number of ways to promote and grow the sector. Life Sciences Scotland brings together the Scottish Government, Scottish Enterprise and senior figures from across Scottish life sciences, including the pharmaceutical industry who are represented by the industry trade body in Scotland, the Association of the British Pharmaceutical Industry (ABPI) Scotland.

Life Sciences Scotland's flagship group, the Industry leadership Group (ILG) is where the industry can engage with the Scottish Government on issues affecting the sector, and it acts as a forum for discussion. The group is co-chaired by a senior figure from the life sciences industry, the Minister for Business, Innovation and Energy and the Minister for Public Health.

33 Abramovsky et al, page 122.

This group also advises the Scottish Government on key issues, for example on its recently refreshed life sciences strategy document.

This ILG is similar to the High-Level Group that the life sciences industry has with the Belgian Government, although the Belgian Prime Minister attends, presumably providing an overview of all areas of policy.

This holistic, strategic view is particularly important. For example, it is difficult to see how a life sciences sector in Scotland can flourish without close links to the NHS and its spending power. Indeed, changes in health care policy – for example the process for bringing new drugs to the market – could have significant implications for the industry in Scotland.

The fact that the Life Sciences Scotland Industry Leadership Group is co-chaired by Ministers from both business and health undoubtedly aims to help ensure close linkages. However, as the Fraser of Allander Institute's Director highlighted in a recent speech[34], it remains to be seen just how well the government's approach to enterprise and industrial policy is fully plugged in – and able to influence and be influenced by – wider health and social policies.

Case Study: The industry in Belgium – the role of government
The Belgian industry is one of the most successful pharmaceutical sectors in Europe. In 2016, it employed 35,250 people, around 4,200 work in research - the industry is estimated to have spent €2.89 billion on R&D. It exported more than €40.7 billion worth of exports, 11.3% of all of Belgium's exports. One of the basic factors underlying its success is simply its history - production of basic chemicals began as far back as the 19th century, and advanced research activity can be dated back to the 1950s. A number of global pharmaceutical companies now operate in Belgium, including Johnson and Johnson, GlaxoSmithKline and UCB, which together employ around 14,000 people. Belgium has a highly-developed cluster of collaborative networks between major companies and universities/research centres - the World Economic Forum's 2017 Global Competitiveness Report rated Belgium 6th (of 138 countries) for the quality of scientific research institutions and 9th in terms of university-industry collaboration. VIB (Flemish Institute for Biotechnology) is a world-leading research institute which links life sciences departments from three Belgian universities. VIB has a total of 65 research groups and conducts basic research across many fields of life sciences. It has concluded over 500 R&D and licensing agreements with external companies, around half of which are based in Belgium. The Belgian government works closely with the industry, particularly through its life sciences High-Level Group (HLG), on which the Belgian Prime Minister sits. This provides practical support to the industry and helps to develop policies that boost the sector's competitiveness. Specific support for R&D and innovation include the Biopharma R&D consultation platform, which involves cooperation between government, major pharmaceutical investors, and the industry trade organisation (pharma.be).The government has also set up a central contact point for start-ups so that they can quickly obtain regulatory support for the development of their activities. The initiative is part of a national innovation office directed by the Federal Agency for Medicines and Health products. Firms receive tax incentives on income derived from new patents and are able to deduct 80% of patent income from taxable profit (the "patent box"). An R&D tax credit is paid on qualifying R&D-related investments. Companies active in R&D also receive exemptions from workforce tax of up to 75% for researchers with doctoral and master degrees.

34 https://fraserofallander.org/2017/05/24/trades-house-lecture-text/

Appendix 1 - Note on definitions used

In the main, this report uses two classifications of the 'pharmaceuticals' sector:

- The first is the narrowly-defined pharmaceutical sector. This covers the industrial activities of production and preparation of pharmaceutical products (Basic pharmaceutical products and pharmaceutical preparations) and relates to activities under the Standard Industrial Classification (SIC) 21. These data are available at sectoral level through both the Scottish Input-Output tables and Annual Business Statistics.

- The second is the 'Pharmaceuticals and Related Sector'. The activities covered in the pharmaceuticals and related sector include activities in SIC 21 (as described above) but additionally activity under SIC 26.6, 32.5, 72.11 and 72.19.

Because 'Pharmaceuticals' (Division 21) is a defined sector within the Standard Industrial Classification system, it is possible to access a range of figures for this part of the Pharmaceuticals and Related sector which is not available for the other components of the wider sector. These include the export and R&D figures for Scotland discussed in the report. Correspondingly, the sectors' definition by SIC makes it possible to compare Scotland's performance against the UK industry.

In Chapter 5 above ('Research & Development Activity in Pharmaceuticals in Scotland'), the figures are published on the basis of Office of National Statistics defined 'Product groups', where responding companies are asked to specify the industry (or 'Product Group') for which R&D was carried out. The figures in Chapter 5 therefore refer to the total amount of pharmaceutical R&D undertaken in Scotland over the period.

The Hypothetical Extraction procedure discussed in Appendix 2 produces an estimate that 'Pharmaceuticals' accounts for the majority (88%) of output produced within the 'Wider Pharmaceuticals and Related' sector.

Appendix 2 - Calculation of total contribution: Input-Output and hypothetical extraction of a sector's activities

To determine the total overall contribution of the sector, the economic accounts for Scotland and detailed analysis are used to undertake a hypothetical extraction of the sector. This models the impact of reducing the output of the sector to zero and replacing all uses of pharmaceuticals and related commodities by imports.

In Chapter 2 when referring to the contribution of the pharmaceuticals and related sector, we first separated the pharmaceuticals sector, as defined in the Scottish Input-Output (IO) tables, from the Scottish Government defined pharmaceuticals and related sector by differencing. The second stage was to allocate the non-pharmaceuticals sector elements of the pharmacy and related sector to alternative SIC classifications. This used guidance from Scottish Enterprise on the activities undertaken by firms operating in the pharmacy and related sector. In practice these non-pharmaceutical sector activities were allocated in proportion to their employment across SIC codes.

For IO analysis, the output of each sector of the economy in question is given by an equation relating total output to the demands for that sector's goods from both intermediate demand (i.e. other industrial sectors) and final demand. Thus, we can specify a set of linear equations of the sort:

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 ... + Y_1$$

$$X_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 ... + Y_2$$

Where X_i represents the output of sector i, and where a_{ij} represents the portion of sector i's inputs that are met by the output of sector j. We can create the column vectors of outputs of each sector (X) and of the final demands of each sector (Y), while calculating a matrix of the direct input coefficients for each sector (the A matrix). The input-output system can then be expressed as: $X = AX + Y$

This expression says that gross output (X) is the sum of all intermediary output (AX) and final demand (Y). If we rearrange this to solve for gross output (X) it can be shown that each sectors output will be given by the equation: $X = (I - A)^{-1}Y$

Where I is an identity matrix, and the term $(I - A)^{-1}$ is known as the Leontief inverse matrix.

The Leontief inverse can be used to examine the degree of interrelationships between sectors within an economy, showing as it does, the extent to which one sector relies upon the other sectors for its inputs. It should also be mentioned that the system described above is the "open" Leontief system where all elements of final demand are considered exogenous. The Leontief system can be closed with respect to households, where the values of the Leontief inverse include not only the direct and indirect purchases necessary to meet changes in demand, but where induced impacts are also included. These induced impacts reveal the wider impact of the increased incomes of workers in sectors that have experienced increased demand for their outputs.

In hypothetical extraction the industry row and column in the A matrix and the industry entries in the final demand vector are also replaced with zeros creating the adjusted A matrix, A^*, and final demand vector, Y^*. The new vector of outputs, X^*, is calculated by post-multiplying the reconfigured Leontief inverse, $(1-A^*)^{-1}$ by the new final demand vector, so that: $X^* = (I - A^*)^{-1}Y^*$

The impact of the sector, as measured by the hypothetical extraction method is calculated as the vector given by $X – X^*$. Summing the elements of this vector gives the output impact. The impact on GVA and employment (and any other variable linearly linked to output) is given $C(X-X^*)$, where C is a row vector of the appropriate variable-to-output coefficients for the individual industries.

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