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SCIENCE AND INNOVATION IN SCOTLAND: A STUDY ON THE IMPACT OF ENHANCED AUTONOMY

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ABSTRACT

The Scottish referendum of 2014 encouraged massive public debate, including on Scotland's scientific performance and its ability to harness innovation and increase global competitivens. The science base in Scotland has traditionally been strong with world leading universities driving development of science. However, the science base has not translated well into innovation. This paper uses statistical data, over 30 interviews and two workshops/focus groups with business and policy leaders to analyse the key scientific and industrial dynamics feeding into the debate and investigate the potential impact of enhanced autonomy on the Scottish innovation system.

Keywords: science, industrial innovation, enhanced autonomy, Scotland

INTRODUCTION

In the wake of the Scottish Referendum of September 2014, there is a risk that attention to some of the issues facing the Scottish economy may fade. The referendum was the setting for arguments regarding Scotland's strengths and weaknesses, and projections of what could happen in different scenarios. Areas of debate included those on Scotland's scientific performance and how to harness innovation to increase its competitiveness in the global economy. It encouraged a high degree of public engagement and prompted the three main political parties in London to promise enhanced devolution of powers and fiscal autonomy if Scotland decided to stay part of the UK.

Regardless of the results of the referendum, Scotland's ability to be a top-level knowledge producer and innovative region is still a matter of interest, and form part of its national image regardless of whether it is independent or continues as a nation and part of the United Kingdom (SCOTTISH ENTERPRISE, 2006; ROPER et al., 2007; SCOTTISH GOVERNMENT, 2008; 2013). The UK Government *Command Paper* (HM GOVERNMENT 2015) contained clauses to implement the devolution commitments on further powers for the Scottish Parliament/Executive, made by the three main UK political parties. In particular, regarding borrowing and income tax powers, the Scottish Government will be able to collect roughly 40% of its own budget and become directly responsible for about 60% of all public expenditure.

Based on this evidence, Scotland is set to enjoy a very high degree of fiscal autonomy, in an otherwise fairly centralised national system of governance. For these reasons revisiting Scotland's scientific and innovation capacities, and the perceptions held by different stakeholders on how these capacities may be impacted by changes in Scotland's institutional structures, can help future research and policymaking.
This paper outlines the perception of Scotland as a strong scientific and innovative society, and outlines the images of Scotland as a region and nation both distinct from England in culture and attitude, and as a participant in the knowledge economy. It will

summarise the strengths and weaknesses perceived and measured in its science and innovation systems, briefly recount policy initiatives to improve them, and outline the main arguments made by the Scottish Government regarding how independence could lead to a more prosperous Scotland.

How can an innovative Scotland best be achieved, as argued during the referendum debate of 2014. The science system has been strengthened during the 2000s as devolution brought a set of new and expanded funding streams in conjunction with existing UK-based institutions. There are questions, however, about the relationship between the science base and Scotland's innovation system, and the lack of coherent policy to address that 'disconnect'. The questions are particularly related to the impact that enhanced autonomy may have on the absorptive and innovation capacities of Scottish business:
What impact would increased autonomy have on the ability of Scottish business to absorb knowledge and apply it to innovative activity?
What impact would increased autonomy have on the organisations that support Scottish businesses in their innovative activities, R&D, technology transfer, commercialisation and finance?
What impact would independence, or increased devolution, have on Scotland's economy in terms of diversity of industry, specialisation and resilience?

Beginning with the concept of imagined community, the paper first traces key background elements of the Scottish science system, and the relationship between science and innovation. Then, it details the present situation regarding Scotland's science base, mapping the institutions that exist to integrate Scottish science policy. It shows that the science system already operates with some autonomy from the rest of the UK. This is followed by an analysis of the tenuous level of connection between science and innovation. The paper will outline the different concerns and opinions of the business and policy communities regarding Scotland's innovation system, and it will summarise the questions being posed by different stakeholders regarding proposed independence and its possible impact on the Scottish Innovation System (SIS). Finally, it presents a summary of the future prospects for science and innovation and an evidenced argument for a less science-led policy led by a focus on new and transformed industrial sectors.

METHOD

To address the research questions, we started by examining the existing conditions for science and innovation in Scotland. Our data collection was framed by two theoretical perspectives. The first is the concept of imagined communities; it draws on anthropological insights to delineate how large communities (i.e. nations) identify and create points of commonality and political development (ANDERSON, 1991). The second is a regional innovation system perspective that includes awareness of evolutionary system change and the importance of institutional factors beyond the region in terms of market access, knowledge creation and other inputs (COOKE et al., 1997). This included extensive review of the primary and secondary literature, as well as analysing the policy documents concerning science and innovation in Scotland over the past 20 years. We also analysed the data for science and innovation in Scotland, together with data on innovation infrastructure and structural features of the economy. We used the Scopus database, OECD iLibrary, Office of National Statistics (ONS) figures, and Higher Education Information Database for Institutions (HEIDI) to develop

an overview of publication record, patent data, research funding, and higher education income in Scotland.

This data collection was then supplemented with information gathering from engaged practitioners, using in-depth semi-structured interviews, undertaken in 2013 and early 2014 before the referendum. The overall approach in selecting interviewees was: first, we interviewed 10 people who held overview knowledge and experience of Scottish science and innovation, as well as practitioners positioned at the interface of science and innovation in Scotland. Second, we undertook a further 20 interviews with senior business leaders, policymakers and academics. The interviewees worked in six key industrial sectors of the scottish economy – life sciences, information and communication technology (ICT), energy, engineering, food/drink, and financial services. Where possible interviews were taped and transcribed but some interviewees declined recording. The material collected was interpreted through analysis and coding to bring out major themes.

Finally, two workshops were held. First, in November 2013, a full day workshop of 16 invited researchers, government, and industry on the future of Scottish science and innovation ran scenarios in two breakout sessions. In the morning, the participants were asked to think about the future of science and innovation in Scotland under Yes/No scenarios concerning possible independence and also leaving the EU. In the afternoon session they were asked to discuss in more detail the barriers and opportunities for Scottish science and innovation under a Yes scenario. A final workshop was held in March 2014 with the objective of testing our results with senior policy makers and business leaders. Both workshops were fully recorded for transcription and analysis.

IMAGINED COMMUNITIES AND SCOTLAND AS A SCIENTIFIC CENTRE

The concept of an Imagined Community (ANDERSON, 1991) is useful to outline the different characteristics that a community shares among its members and the accompanying expectations of that community. Regarding Scotland, the concept has been used by different authors to discuss its national image, and its regional distinctiveness in Britain. Scotland as an innovative nation/region has been an established image, held up as an example of scientific excellence within an ancient university tradition, which has also been put forward as a source of potential cultural, social and economic strength. The strength of Scottish science and industry was lauded during the Edwardian era, and continued up to the Second World War, from which point a narrowing of performance between English and Scottish science occurred, and industrial fortunes began to shift away from Scotland (EDGERTON and HUGHES, 1993).

Despite these changes during the 20th century, Scotland in the 1980s was still described as ‘an economy carrying out substantial levels of research in both the private and public sectors, with a total R&D intensity significantly higher than that for economies of comparable size’ (EDGERTON and HUGHES, 1993 p. 11). Yet the scientific strength, R&D capacity, and innovative activity were mostly concentrated in the universities, and in the subsidiaries of large multinational companies (MNCs). The Scottish imagined community has contributed to a sense that Scotland can achieve clusters of technological or innovative excellence, regardless of the real limitations it may face. An imagined community, as described by Anderson (1991) is based on some historical facts, but more importantly on community myths which may be imperfect.

Edgerton and Hughes (1993) mapped the massive drop in government R&D in the 1980s, particularly the fall in government support for industrial R&D but showed that 1.8% of Scotland's GDP was spent on R&D, and that Scotland did as much R&D as Austria, Norway and Denmark. They also showed Scotland's 'comparative advantage' in university education with about 14% of the UK academic staff, though Scotland's share of research council funding at that time was lower than now at no more than its population share (8.8%) in 1991 and 8.3% in 2013.

The research was a useful benchmark from which to analyse the post-devolution period, compare its policy proposals with what has happened in the last twenty years, but also with the possibilities for the science and technology future of Scotland. Edgerton and Hughes welcomed the proposal for a Scottish university funding system (which was set up and is now the Scottish Funding Council - SFC), argued against university selectivity and concentration, and called for more government funds towards industry R&D to create a diversified industrial R&D base.

UK AND SCOTTISH SCIENCE AND INNOVATION POLICY

Devolution in 1999 brought autonomy for the Scottish parliament and government on a range of issues that relate to knowledge base development, research and science funding. The Scottish Government allocates the budget for the economic growth strategy, which covers the research and innovation strategy, and funding policies. The SFC is the body responsible for teaching and learning, science and research, knowledge exchange, innovation and other activities in Scotland's universities and higher education institutes. It has developed some original approaches, for example:

- A 'pooling' initiative, developed after 2001, to strengthen a diverse range of research in subject areas where the SFC felt that scale and strength could be improved through Scotland-wide collaboration. Subjects such as chemistry, physics, engineering, geoscience and environment, economics and the life sciences were supported and the research evaluation results of 2008 and 2014 showed significant improvement.
- A fund for innovative activities, used to attract big research initiatives to Scotland.
- A set of Innovation Centres, from 2012, to help link Scottish research with industrial innovation, with eight centres so far (digital health, stratified medicine, sensors and imaging systems, industrial biotechnology, oil and gas, construction, aquaculture, and data lab).

In addition, Scotland benefits from the support provided by UK-wide bodies, including: the seven research councils that fund research across the UK, collectively called Research Councils UK (RCUK); and, the Technology Strategy Board (TSB)/ Innovate UK, the UK agency that supports UK-wide development and commercialisation of research.

In industrial innovation there have also been a series of initiatives. The Scottish Development Agency (SDA) was established in 1975 in response to the significant decline of Scotland's traditional industries. In the 1980s, it moved from supporting the restructuring of traditional industries to encouragement of new high tech industries into Scotland. Its early success was not sustained into the 1990s as much relocated industry could not compete with East Asia. The SDA's successor, Scottish Enterprise (SE), attempted to build on the strength of a range of industries, such as oil and gas, finance, chemicals, electronics, food and drink (beef, fish, whisky), and start a life science sector.

SE took up a cluster development strategy (SE 1996) and began to build networks and support structures, an approach recommended by the Monitor Group (1996). The cluster strategy aimed to build on areas of knowledge strength, and Scotland's image as a producer of good science; for example, the biotechnology sector was identified by SE as a high priority mostly based on the research capacity in Scotland's university sector rather than any actual industrial presence.

These interventionist approaches in Scotland stood out well before devolution in 1999 and continued thereafter (ASHCROFT et al., 2006). SE pursued a multi-strand innovation strategy, outlined in *Smart, Successful Scotland*, (SCOTTISH EXECUTIVE, 2001). This included a Business Growth Fund, Proof of Concept Fund, Scottish Co-Investment Fund, and creating the Intermediary Technology Institutes (ITIs) in three cluster areas, though these had quite a short and less successful life, as analysed by BROWN et al., 2015. It developed programmes, such as Careers Scotland for skills and learning, and programmes to attract FDI and talent to Scotland, such as the Scottish Development International and the Global Scot network. SE programmes have been successful in creating a funding base for new firms, including an extensive business angel network; encouraging growth in different technology sectors; facilitating spin-outs from universities; and raising Scotland's profile in the knowledge economy.
Several reviews of the Scottish innovation system have been published (ROPER *et al*, 2007; COAD and REID, 2012; LEVIE *et al*, 2013), which praise Scotland's scientific R&D performance in the universities, but highlight bottlenecks and a disconnect between the scientific knowledge created in Scottish universities and the knowledge demands and capacities of local Scottish firms.

Strong Science

Corresponding to the image of scientific excellence, the science base in Scotland has traditionally been strong, with world-leading universities driving the development of science. Various studies have confirmed the achievements and significance of Scottish science (SCOTTISH SCIENCE ADVISORY COUNCIL - SSAC, 2009; THE SCOTTISH GOVERNMENT OFFICE of the CHIEF SCIENTIFIC ADVISOR, 2007). We used research publications per million population as an indicator of this strength. We use this indicator to avoid the problem with absolute publication records and output per GDP as comparators of countries with different populations and income. We analysed the publication record from 1996-2012.
We begin with the life sciences because of the strong reputation that Scotland holds for research in life sciences globally. Figure 1 presents the data from 1996-2012. Scotland performs very well in this area of science, though not quite so well as other small prosperous European nations, such as Switzerland, Denmark and Sweden.

Figure 1 here

However, not all areas within the life sciences rank equally well. Table 1 presents publication record data in different areas of life sciences. It shows that Scotland publishes particularly well in agriculture and biological sciences, biochemistry, and immunology, but is not as competitive in pharmacology, toxicology, pharmaceutics, and medicine.

Table 1 here

Scotland's performance in physical sciences is excellent: Figure/Table 2 present Scotland's publication record in the area of physical sciences. The table suggests that Scotland's science base is stronger in physics and astronomy, computer science, chemistry, chemical engineering, and energy whilst weaker in engineering and material sciences.

Figure 2 here

Table 2 here

Innovation in Scotland: a 'disconnect' between science and innovation

Scotland's science is relatively strong, though perhaps not necessarily best suited to its local industrial needs. Different innovation indicators show a mixed message.
One indicator of innovation – albeit contested – is the patent record, which is relatively poor for Scotland (see figure 3). For instance, with 68.5 patents per million head of population, Scotland generates four times fewer patents than Finland, significantly fewer than countries like Sweden, Japan, Germany, US and and even less than the UK average (OECD, 2015).

Figure 3 here

Our research suggests several reasons for a weak relationship between science and innovation. First, Scotland does not exploit its human capital as much as it potentially could. 36.9% of Scotland's labour force has tertiary education, which compares well with some other innovative countries (e.g. 35.3 in Finland, 30.4 in Sweden and 25 in Germany). However, while Scotland fares well in employment in knowledge-intensive services (42.8% of its total employment) in comparison to other countries (e.g. Finland with 41.1% and Germany with 35.3%), in relative terms the highly educated labour force in Scotland has been less significantly employed in high and medium-high technology manufacturing sectors. Scotland's 3.9% employment in high and medium-high manufacturing is considerably lower than other innovative countries (e.g. Germany with 10.9%, Finland with 7%, and Norway with 4.3%) (OECD, 2015). In addition, there is evidence that Scotland is weak in cultivating commercial and managerial skills that are critical for developing innovations out of basic science (DANSON, 1995; ROPER *et al*, 2007; FREEL and HARRISON, 2007; COAD and REID, 2012; LEVIE *et al*, 2013). As one engineering business leader interviewee argued: 'There is an issue with skills for growth and there is lack of leadership, finance, operation, and organisational skills [which has resulted in start-ups] filled with entrepreneurs with technical knowledge but lacking commercial experience'.

Interviewees cited the dearth of senior managers capable of running large-scale corporations and starting big initiatives, and there are few large companies in Scotland to attract or retain experienced managers. Few large companies means that there are not enough role models for SMEs to emulate which, in turn, means that more experienced entrepreneurs leave Scotland creating a hole in the entrepreneurial skills base.

Another problem relates to the level of funding for R&D. Scotland's percentage of total R&D expenditures to GDP (at 1.7% lower than in the early 1990s) is lower than other innovative countries (e.g. 3.9% Finland, 3.3% Japan 2.8% Germany) - see figure 4 -

Figure 4 here

lower than other strong science regions within the UK (e.g. East and South England with 4.3% and East of England with 2.1%) in 2010. The data reveal that this disparity is mostly driven by the lower performance of the business sector**.** The percentage of R&D expenditure to GDP performed in Scottish higher education (0.81%) is higher than the UK average (0.52%) and is akin to other benchmarked countries (0.9% in Sweden, 0.72% in Finland and 0.56% in Norway). However, R&D expenditure by business in Scotland (0.59% of GDP) is considerably less than other innovative countries or other innovative regions within the UK, and is even less than the UK average (1.1%) (OECD, 2015).

Figure 4 here

Figure 5 shows the breakdown of Business Enterprise R&D (BERD) sources in Scotland from 2001-2011. As the figure suggests, in general, the level of own funding and government funding has been increasing, while the level of funding by other UK businesses has significantly declined especially since 2005. The level of BERD has increased over the last decade. However, the increase in Scotland was from an extremely low base. Scotland spent less than 4% of total UK BERD in 2011, relative to its size (8.3% of population and 8.0% of GDP).

Figure 5 here

Over recent years, the business angel investment model in Scotland has matured and has contributed to the growth of investment. However, the situation is not so good with larger venture capital investments (over £2 million) (HARRISON and MASON, 2012; MASON et al., 2013). In 2009, 2010, and 2011, only 11, 15, and 10 deals, respectively, over £2 million were reached and most investors do not invest on a regular basis. These figures suggest that Scotland fares worse than other UK regions in securing large VC funds. The limited level of VC support makes it hard for angel investments to lead to 'companies of scale'. As one of our angel business leader interviewees articulated: 'Penetrating global markets needs VC investment which is absent in Scotland'.

Finally, the strengths in science do not map onto the existing industrial system in Scotland. One example is the concentration of research council funding on biology and the medical sciences (53%) in relation to the main sectors of the economy. The life sciences industrial sector is growing but not yet firmly linked to the research base. Scotland has articulated a strategy of diversification from finance and oil and gas towards sectors such as information and communication, life sciences, engineering and renewables. A recent strategic priority has been to encourage internally driven growth based on local capabilities, to use Scottish capabilities to bridge the gap between science and innovation. This approach depends strongly on building entrepreneurial capacity - to which we now turn – in areas such as biotechnology and renewal energies, and expanding it in areas such as ICT.

Entrepreneurial activities

The reason VC investment is important is that entrepreneurial activities and aspirations in small and medium size enterprises are also known to be a driver for innovation. Total early-stage Entrepreneurial Activity (TEA) is a measure used by the GEM (Global Entrepreneurship Monitor) team for evaluating and comparing entrepreneurial activities in 69 countries. TEA is the proportion of people who are involved in setting up a business or owner-managers of new businesses. Among the Arc of Prosperity AOP countries, Finland and Denmark show signs of increased TEA (figure 6). The TEA rate in Scotland grew by 11% from 2011 to 2012, lower than the UK but higher than the other comparator countries.

Figure 6 here

In comparison to the arc of prosperity (Scandanavian) countries Scotland appears to be weak in networking, opportunity perception, process innovation, product innovation, high-growth aspirations, and quality of human resource, while it is strong in technology, competition, opportunity start up, and cultural support variables. In general, the data suggest that Scotland is weaker in areas that relate to attitudes and aspirations and is not particularly strong in forming and harnessing collaborations and networking (figure 7). Lack of collaboration between companies and academia can decrease the capacity of companies to acquire and absorb knowledge from academia and each other. Overall, our use of patent, industrial R&D, business investment and entrepreneurship data shows weak industrial innovation capabilities in Scotland with rather weak improvement since devolution.

Figure 7 here

THE FUTURE OF SCOTTISH SCIENCE AND INNOVATION

The 2014 referendum drove a significant debate about the nature of innovation in Scottish society and economy, and under what conditions it could better harness its scientific strengths and correct its weaknesses and bottlenecks. The UK government and Scottish government detailed very different scenarios for science after independence. The Scottish Government white paper argued for retaining the current integrated research system that it called the ‘common research area’ (SCOTTISH GOVERNMENT, 2013). It claimed that independence would lead to a stronger Scottish economy through Scottish control of fiscal and monetary policy, and thereby provide a more business and innovation friendly environment. It argued that a more ‘coherent framework for supporting innovation across the economy’ would be possible, and that it could be targeted specifically at key areas of strength and weakness (p. 111). It also argued that it would be better able to use specific policy levers, including ’financing levers such as the provision of loans and guarantees, competitive grants, innovation vouchers, the establishment of an Innovation Agency or Institute’ and the indirect levers of tax-based incentives (p. 111).

In its report, the UK government warned that independence would have meant the abolition of the integrated research system, meaning that Scotland would have to build its own research system (HM GOVERNMENT, 2013). In this case the Scottish universities would have lost their access to the disproportionately high research funding

they enjoy. The UK government noted that together, Scotland and the rest of the UK have a thriving research base which is highly respected across the world. Furthermore, 'Researchers from across the UK currently benefit from a highly integrated and interdependent, well-aligned system. This facilitates collaborations between researchers across the UK, as well as projects with industry and overseas academics'. (p. 7).
Given these diverging visions,a number of cogent questions remain open. What might enhanced autonomy mean for Scotland and its system of innovation? Will there be more cohesion in innovation policy, and will it address the bottlenecks in the system? Will the changing boundaries of markets and policy regions have a positive, negative or no effect on Scotland's ability to be innovative?

With the above discussion in mind, we address our three major questions:

1 What impact would enhanced autonomy have on the ability of Scottish businesses to absorb knowledge and apply it to their own innovative activity?
2 What impact would enhanced autonomy have on the organisations that support Scottish businesses in their innovation activities, R&D, technology transfer, commercialisation, and finance?
3 What impact would independence, or more devolution, have on Scotland's economy in terms of diversity of industry, specialisation, and resilience?

Impact of enhanced autonomy on science base and industry innovation

We have shown that there is a clear discrepancy between the disciplinary focus of the research base, and the structural features of local industry. BERD within the company base is generally low, although there is wide variation across different sectors. The absorptive capacity in the local business base is weak. There is interaction between larger Scottish-based international firms and the research base, but growth of indigenous technology firms remains weak. So, one of the issues we addressed with interviewees is whether a more devolved Scotland would be better able to alter elements of its innovation system, or whether removing itself from the large market and resource base of the UK would have a negative impact.
In the sections that follow, we outline the thoughts of different industrial, policy and academic leaders in Scotland on how a changed status for Scotland would impact organizations innovative capacity, as well as the institutional structures that make-up Scotland's system of innovation.

One interview focus was whether enhanced autonomy would make any substantial difference in local firms' ability to absorb knowledge and skills from local and/or external sources. The issues of 'learning' and 'absorptive capacity' (COHEN and LEVINTHAL 1998) are seen as crucial in the systems of innovation and knowledge-based view of the firm literatures. The regional system itself is often depicted as a complex configuration of knowledge assets and cognitive networks, whose architecture and internal routines shape research/industrial activities *vis-à-vis* processes of knowledge creation, transfer and exploitation, as well as determining asymmetries in knowledge endowments which ultimately lead to competitive advantage (FLORIDA, 1995; MORGAN, 2007).
In terms of organizational ability to generate knowledge, our interview data exposed the concern that independence may jeopardise the ability of Scottish HEIs to attract funding from a variety of UK sources, including research councils, UK government and charities.

Furthermore, in terms of exchanging knowledge, Scotland was seen by some of our interviewees as benefiting from the UK-wide support infrastructure and networks, which

allow local HEIs to expand their networks throughout the UK and beyond. While our interviews included representatives from five different industrial sectors, fears were particularly acute in the life sciences area, where local players sense that Scotland is yet to reach a critical mass of firms, individuals and accessible capital. As markets and opportunities for strategic collaborations are clearly global, the industry appears to be partly reliant on UK-wide scientific and financial networks. Similar – albeit milder – concerns were expressed for the ICT sector.

In contrast, training and absorption of skills (including graduates) were not seen as a problem which would be particularly affected by more autonomy (be it independence or devolution). Some interviewees felt that more autonomy could provide the tools for developing further programmes (e.g. more investment in vocational training), with the needs of the key sectors of the Scottish Economy in mind. Training is already devolved, and the current economic strategy (SCOTTISH GOVERNMENT, 2011) already aims to create an education system that is 'responsive and aligned to demand ... to support employers by better understanding and assessing the skills required for future success and ensuring that the supply of skills, training and qualifications is sufficiently responsive' (p. 126). In this sense, more autonomy regarding the overall budget was seen as a potentially positive factor, as it would allow for a wider margin of manoevre and the development of an approach more tailored to Scottish needs. This position seems in line with the result of the Heseltine Review (BIS 2013) and also Gardiner et al (2013) on rebalancing the British economy from a geographical standpoint.
Interviewees from both the life sciences and ICT sectors lamented a lack of critical mass and soft infrastructure (such as financial networks) for cluster emergence. Reflecting on the possible impact of more autonomy with enhanced powers provided to the Scottish Government, one key factor pinpointed by interviewees was access to quality human resources (experienced managers, as well as scientists and technicians). For instance, the paucity of managerial skills to be employed by new ventures is an ongoing problem for emerging sectors of the Scottish economy (ROSIELLO, 2005), whereas Levie (2013) points to the relatively low number of female and senior entrepreneurs compared to the rest of the UK..
Some of the research-intensive fields in Scotland do attract significant research funding and are highly competitive, but a stronger industrial base is needed to retain the graduates of these programmes, and, as a consequence, Scotland is a net exporter of this talent. One industrial association interviewee noted that: 'While it's acknowledged that we do have the world class research base, there's a real and persistent challenge about absorption of that knowledge particularly among our SMEs'.

Another interviewee, from IT, added that:

> the issue on management talent is we do not have multi-nationals running the business from here. We have satellite R&D teams, not complete bits of the business, so we don't have managerial training effectively on taking risk and getting product definition right, and that's one of the big inhibitors on the whole management stream, and the ICT space, I think the management skills issue is the biggest issue we have, not finances.

Other interviewees had the view that fully-fledged independence would aggravate existing difficulties in recruiting and retaining business and scientific talent. One of them, from biotech business, referred to the 'Commercialisation Enquiry Final Research

Report' (ROYAL SOCIETY of EDINBURGH, 1996) on lack of financial management skills and noted that:

> It's worth reading it again and seeing what the position is compared to the early 90s. The companies have changed position, the tools are better. There's more availability of venture capital, there's definitely more availability of business angels, you can fund businesses to a certain extent, but there are fewer public companies. Now we all know the issue, the marketplace. But the ability to raise money and float a company is seen as another tick in your management expertise. There are very few people in Scotland, particularly within the life science sector, that have actually done that in the last 15 years. So we've effectively no flotation. So that's a key management skill that does not exist in the community in Scotland; you would have to go outside to find those sorts of things.

Other business leader interviewees commented that their business perspective was already international, and that they make investments and draw on talent outside of Scotland's borders. Independence might cause some operational changes, but the strategy would stay the same.

Oil/gas and financial services are key sectors of the economy that seem less reliant on the local education/research base and training institutions. Interviewees from these sectors felt that processes of cluster emergence, cumulative learning and competence/skills development had occurred over the past decades within the business environment. The oil/gas cluster located in Aberdeen and the financial services industry situated around the city of Edinburgh have nurtured the production of personal skills and technological capabilities that are now deeply anchored within the local economies. Nevertheless, a frequently cited example of dysfunctional elements within the Westminster/Edinburgh system of governance is the current immigration policy framework. A significant number of interviewees felt this was preventing the Scottish economy from attracting much needed skilled workers.

In summary, the views of business leaders on the likely impact of independence on absorption of knowledge to build improved innovative capability in firms vary by sector and skill. There is general awareness of the mismatch between the research and knowledge base and the industrial system in Scotland, but less specific consensus on what might be done. This may be because businesses can tap into research and knowledge anywhere and not just within Scotland. But it also may be because there are weak systems to make businesses aware of what knowledge exists. Overall, business leaders and policy makers tended to speak more terms of science and its application than of a pulled together innovation system. On the other hand, there is clear agreement that new policies and practices are needed as further devolution unfolds.

Impact of independence on innovation infrastructure

Sustaining and growing successful and innovative industries depends on a range of services and policies (MULLER and ZENKES 2001; MORGAN 2007). Our interviewees emphasised that a key factor shaping the innovative capacity of local firms and sectors is the preservation and expansion of the existing infrastructure for supporting innovation, alongside changes in the tax regime, changes in the regulatory environment, and preserving excellence in the higher education system A wide range of such powers and services are already devolved, including:

- Development of a skills base that is responsive to the needs of business

- Tailored support to key sectors – creative industries, energy (including renewables), financial and business services, food and drink (including agriculture, and fisheries), life sciences, sustainable tourism, and universities
- Horizontal support of innovation and its commercialisation, such as the SMART, the Proof of Concept Programme, and the financial products available to local businesses.

The Scottish Department for Enterprise, Energy and Tourism, the responsible government department, had a budget of £410.7m in 2011. This included £45.2m for industry and technology grants, £283.4m to the enterprise bodies (Scottish Enterprise & Highlands and Islands Enterprise) and an Innovation & Industries budget of £5.8m.
In spite of the currently devolved powers, the Scottish Government argued that independence was essential to develop a more effective policy mix to support innovation: **'**Independence would provide an opportunity to […] develop a more aligned and coherent framework for innovation in Scotland. A key goal must be to develop a virtuous cycle of activity with close collaboration between key partners in the innovation system – including universities, funding providers, firms and public sectors agencies – behind coherent strategic priorities linked to additional economic levers.' (SCOTTISH GOVERNMENT, 2013, p 118).
Those who support more devolution or independence focus on the advantages brought by a more comprehensive and better coordinated strategy, tax incentives for innovation, an immigration policy aimed at attracting skilled workers, and a more active role for the public sector in promoting innovation. With regard to this coherent industrial strategy approach, one oil and gas business interviewee made the following observation:

> If I can take you back a moment to the early days of North Sea oil and gas development, at the time, Scotland and England were characteristically different. […] They were not in the short-term markets of the City of London. They were in it for long-term capital growth. […] Now it seems to me there's an element of that in the current debate about what happens next. Scotland is still wealthy in a lot of resources. For instance, it is land-rich, huge potential in terms of the next 100 years when land is going to be at a premium, wherever you look anywhere in the world.

The cases of Norway, Switzerland and Denmark were also cited as examples of small countries with frameworks of innovation support that have been strategically and coherently developed according to the evolving needs. An IT business interviewee observed that:

> I think there's every reason to suppose that it won't be easy, it might be a messy period for a while. So, the whole of the Scottish economy might not do very well for 10, 15, 20 years. Hopefully not longer than 10 years. But then, I do think there's no reason on earth why Scotland couldn't configure its economy to be more like a Scandinavian country. … These are among the most prosperous countries in the world and the quality of life in them is very good, there's no particular reason why we shouldn't be in that situation.

Sceptics of enhanced powers to the Scottish Government and an autonomous Scottish innovation strategy pointed out that emerging sectors of the local economy are currently reliant on the support of Innovate UK (IUK). IUK has taken on a wide range of innovation support. IUK also facilitates the delivery of Knowledge Transfer Networks (KTNs) and a variety of *Catapult* sectorial activities, and have very significant funding

(£1bn per annum). IUK spans a greater policy and delivery range than Scottish Enterprise, acting as a more equal partner to funding councils and medical charities in UK science and innovation policy. Scotland received some 10% of IUK funding in 2012. Finally, some interviewees felt that the UK Government had more potential in public procurement, for instance in defence-related contracts to Scottish engineering companies. But even the skeptics were in favour of improved innovation infrastructure and spoke of their willingness to support initiatives.
To sum up, our interview data allow identification of key issues of particular concern regarding the preservation/expansion of existing innovation infrastructure - namely the need for an effective mix of policies that needs to be context-specific and ranges from procurement, to instruments which glue the local innovation systems to global markets, to the creation of centres of technological excellence where public and private players are able to mix knowledge and collaborate. The general consensus was that the strengthening of such infrastructure in Scotland should not come at the expense of a reduced access UK level infrastructure, which provides a series of benefits arising from its larger scale.

Innovation and structural change

Interviewees from emerging sectors voiced different concerns regarding devolution or independence. Research-intensive industries, such as ICT and life sciences were more interested in R&D tax credits, grants for innovative projects, and private equity/credit available for risky projects/entrepreneurial ventures. In this sense, the existence of a Scottish Investment Bank was seen as a positive feature of the existing Scottish innovation system. The recession of the past five years created profound challenges for many companies in accessing capital beyond the early stage equity market. In response, the Scottish Executive rebranded Scottish Enterprise's investment team as the Scottish Investment Bank in December 2010. Crucially, it expanded its remit to support the development of Scotland's private sector SME funding market to ensure that both early stage and established companies with growth and export potential have adequate access to growth capital. Some of our interviewees saw this as an important development, a model for supporting investment in local ventures that should be preserved and extended in an independent Scotland alongside tax reliefs such as the Enterprise Investment Scheme and R&D tax credits.

According to our interview data, innovation and structural change will take time since emerging sectors, such as life sciences and renewable energies are in an embryonic stage of development, whilst ICT has not yet reached critical mass. Further, they not only depend on increased investments, but also on crucial factors in the regulatory environment. Economic activities in sectors such as oil/gas, financial services, ICT and bio-pharmaceuticals are critically dependent on rules dictating how natural resources can be extracted/handled, drugs safely produced, financial services prudently and transparently offered, and intellectual property used. Some interviewees raised the issue of new regulatory frameworks, the time needed to develop them, and whether Scotland has the financial/human resources to put them in place. One biotech company interviewee said:

Currently in the healthcare system for example, when you invest in a company in the UK that's got a UK market, you deal with the MHRA. You know how the process works. In an independent Scotland the regulator is not based in Scotland. You may contract with

the MHRA, but how does that work? My biggest concern is anything that creates doubt in the venture capital organisation.

The Scottish Government highlighted that nurturing and promoting an entrepreneurial culture would constitute a strategic priority, to boost competitiveness and reindustrialise the new country. Many interviewees agreed that this constitutes a desirable target, very much in line with the existing economic literature, which shows that the combination of innovative investment and entrepreneurial capacity is a key driver of growth in developed economies (CORRADO et al 2009).

Crucially, as autonomy is enhanced, our interview data suggests that the current infrastructure to support innovation and entrepreneurship would have to be maintained and improved. Some interviewees felt that independence would push local economic agents to take more direct responsibilities and policymakers to develop the conditions for a stronger entrepreneurial culture. At the same time, our interview data shows that issues concerning access to the UK/European market and scientific/industrial networks.

CONCLUSIONS

The paper set out to understand the key issues regarding innovativeness within the Scottish economy in the wake of the referendum of 2014. It used the concept 'imagined community' to frame the lasting image of Scotland as a strong scientific and innovative society both distinct from England in culture and attitude, and a major participant in the UK's knowledge economy. The paper provided strong evidence for Scotland's world class science. But the image of a strongly innovative Scotland is less evidenced. We describe perceptions of the serious 'disconnect' between scientific/educational capacity on the one hand, and innovativeentrepreneurial capacity on the other.The paper has provided data on the main concerns and informed opinions of the business, policy and research communities concerning the Scottish innovation system.

After Scotland decided to stay part of the UK, much enhanced fiscal autonomy is under way. On the basis of such imminent transformation, the questions raised in our interview-based study remain open and extremely relevant. What are the prospects for science and innovation? and how could enhanced autonomy improve innovation in the Scottish economy? Our interviews, workshops, and policy and secondary data, point to a series of conclusions. First, the interviews and workshops showed that the desire for a more aligned and coherent innovation policy is generally shared among the business community. However opinions diverge as to whether such strategy could be more effectively delivered by a Scottish Government benefiting from full autonomy vis a vis micro-economic and innovation policy, or through a realignment of the responsibilities and powers within the UK-wide system of innovation.

Second, the researcher community see possible reductions in research funding as a major threat to the Scottish research universities and research institutes. The business community see the Scottish universities as a huge advantage to economic competitiveness, but some, a minority, also think that an innovation-led policy might also change research priorities, at least to an extent.

Third, there is a general awareness of the current disconnect between the science base and the industrial sectors of the Scottish economy.

Fourth, there was also a general consensus that structural change within the Scottish economy is required to secure long-term prosperity. The emergence of a stronger entrepreneurial culture is seen as a *sine qua non* condition to take advantage of the potential for innovation that resides within/at the interfaces of emerging sectors of the economy such as life sciences, ICT, renewables and engineering, but also food/drinks and tourism.

Fifth, there was major uncertainty about the options as the process of enhanced autonomy gets under way. One uncertainty related to possible changes to the tax regime. In this respect, views tend to vary dramatically depending on the needs of different industrial sectors. There was a general consensus, however, that the options available to the Government of a more devolved or even independent Scotland would be highly restricted.
In general, our research questions, focused though were on the independence debate, brought a series of answers that showed concerns and pressure for change under any form of governance. The status quo received no support though independence was not seen as a panacea either. The debate brought out a wide range of concerns about future innovativeness in the Scottish economy.It is our contention that the ongoing debates around enhanced autonomy should provide opportunities to broaden arguments and bring changes to innovation policy and practice. The independence debate might have provided an opportunity to move from the traditional argument that in Scotland 'science is good, innovation is weak' towards a policy debate based on how to bridge the science-innovation gap and thus how to translate from science to commercialisation.

An alternative policy approach that has received much less attention in Scottish policy circles is how to go beyond starting with 'good science' and instead look at existing and potential economic activity in Scotland so as to improve the innovative potential across the broadest range of industrial sectors – an integrated innovation systems approach. An innovation systems perspective could build on specific application areas, such as food and drink, oil and offshore resources, industrial biotechnology, renewables, construction, finance, higher education, and so on, to support the diverse capacities and linkages needed to strengthen the connections between industry and Scotland's science, business and innovation base. The imaged community of Scotland as a global scientific and innovation centre will depend on an entrepreneurial state (MAZZUCATO, 2013) with an integrated raft of 'smart specialisation' activities and institutions (FORAY et al, 2009) focused on existing and emerging industries and services.

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Table 1: Publications per million population in different areas of life sciences

Country	Total publication in Life sciences	Agriculture and biological sciences	Biochemistry, genetics and molecular biology	Pharmacology, Toxicology, and Pharmaceutics	Medicine	Immunology and microbiology
Switzerland	16673	3827	8607	1965	5215	198
Denmark	14685	4652	7329	1499	4648	312
Sweden	14232	3735	7319	1516	4775	194
Finland	12025	4069	5547	1212	3848	188
Scotland	**11171**	**4217**	**6153**	**1058**	**3144**	**172**
Netherlands	11109	2794	5409	1273	4131	170
Norway	10613	4453	4404	807	3179	130
United Kingdom	9044	2417	4526	1178	3005	109
Belgium	9039	2639	3821	1226	2874	130
United States	7308	1745	3821	879	2212	76
Germany	6391	1545	3353	774	1911	86
France	5807	1567	3014	657	1737	71
Italy	5042	1171	2667	712	1807	46
Japan	4256	953	2467	684	1250	105
China	387	116	202	61	91	5
India	208	76	84	56	37	4

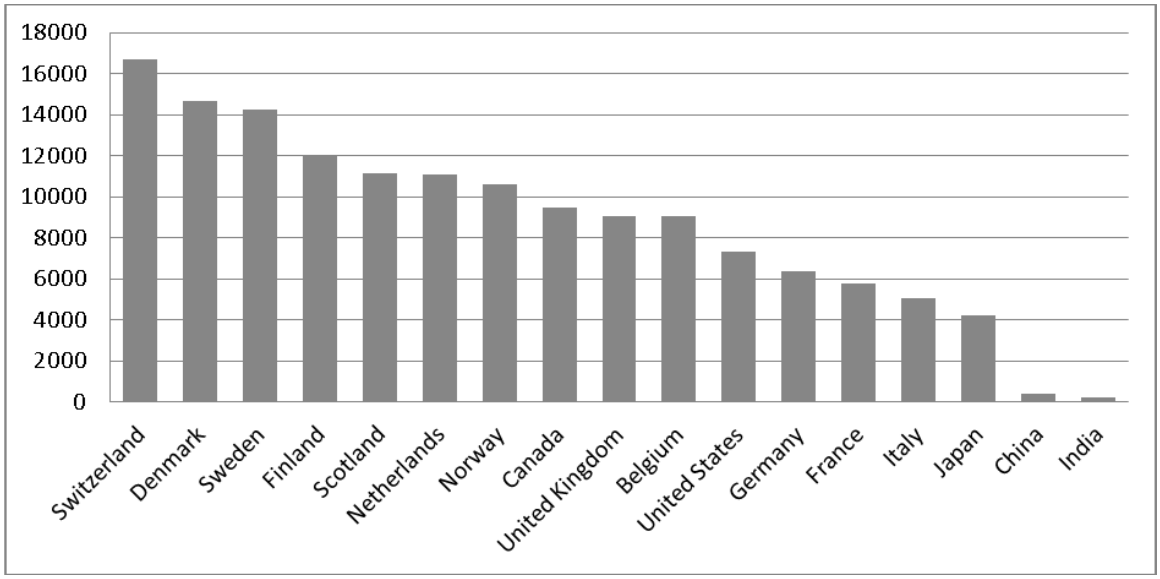
Source: authors analysis of Web of Science

Table 2: Publication in science in different areas of physical sciences

Country	Physical Sciences	Engineering	Physics and astronomy	Material Sciences	Computer science	Chemistry	Environmental sciences	Chemical engineering	Energy
Switzerland	26124	6254	8483	3775	3671	4541	2547	1684	812
Finland	19388	5590	4693	2601	3933	2339	2825	1473	583
Sweden	19357	5497	5233	2947	2689	2963	2663	1332	805
Denmark	16900	3877	4413	1779	2482	2622	2630	1092	770
Norway	16115	4116	2665	1438	2493	1671	2927	1092	1117
Scotland	**15907**	**3542**	**4495**	**1853**	**2688**	**2488**	**2032**	**1465**	**601**
Netherlands	14573	4060	3671	1829	2487	1984	1857	1101	531
United Kingdom	13668	3975	3371	1807	2120	1937	1526	840	466
Belgium	13410	3804	3948	2179	2171	2342	1348	886	431
Germany	12310	3085	4033	2239	1693	2161	949	860	392
France	11127	2849	3505	1889	1683	1865	776	739	329
United States	10899	3807	2564	1391	1730	1406	1140	720	406
Japan	8450	2839	2653	1866	1087	1603	399	650	320
Italy	8387	2350	2564	1069	1355	1315	632	474	261
China	1774	773	349	337	342	255	89	134	91
India	414	110	97	84	59	104	42	40	18

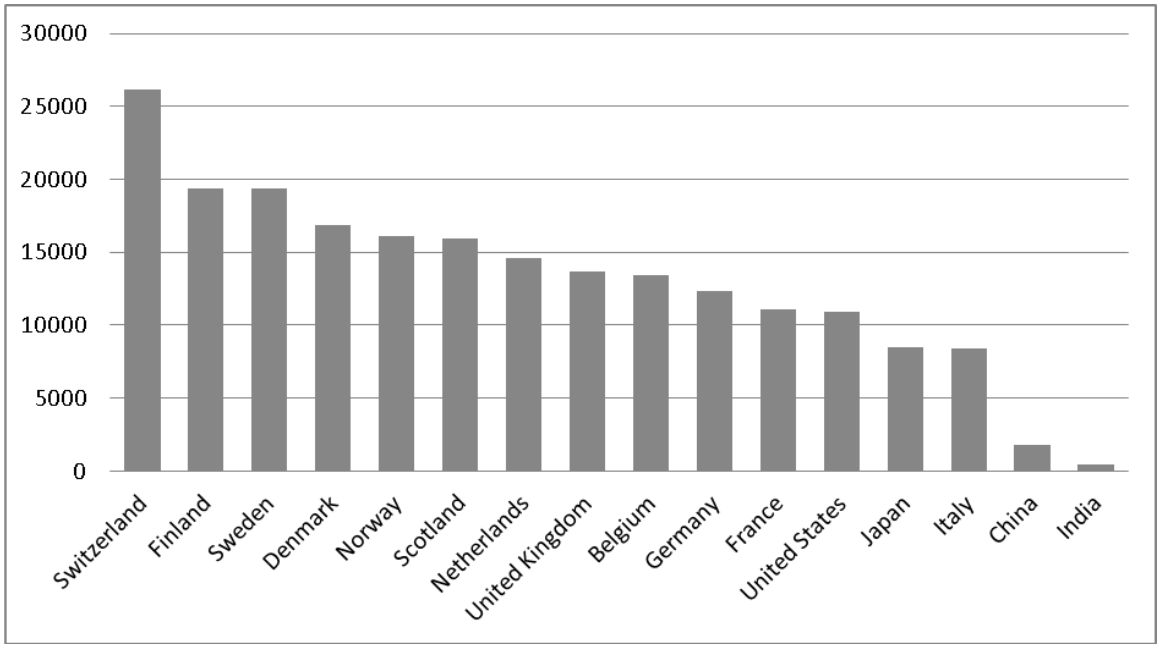
Source: authors analysis of Web of Science

Figure 1: Publications in life sciences per million population (1996-2012)



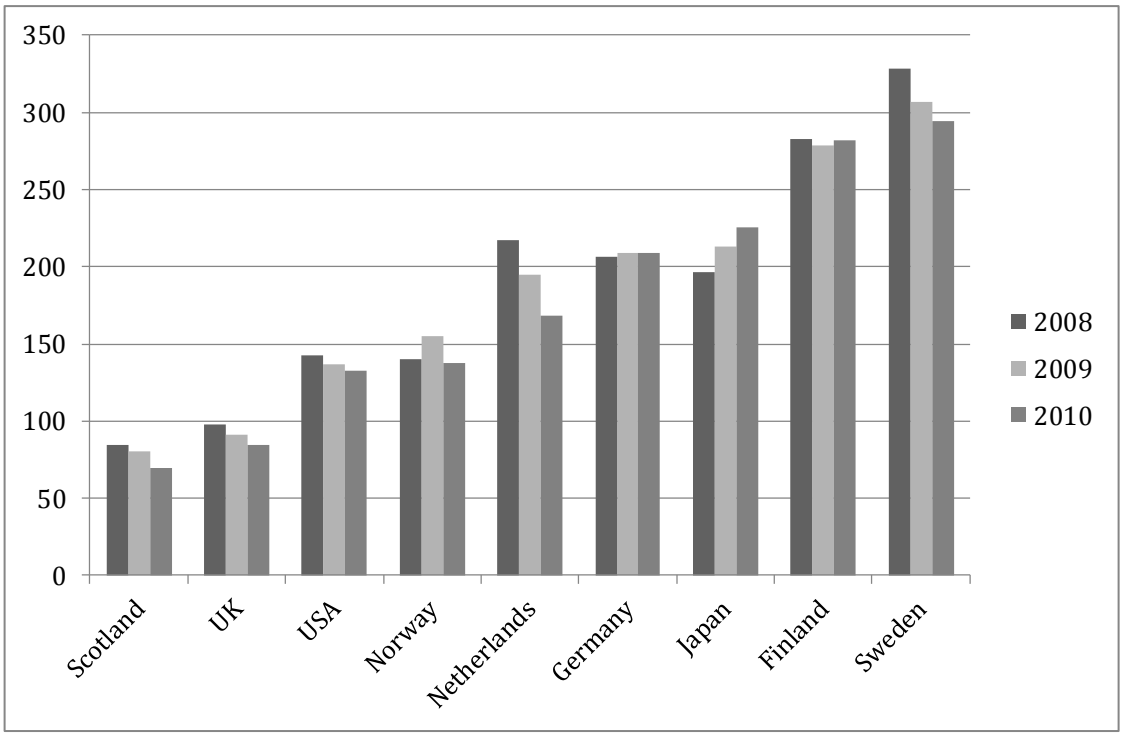
Source: Authors analysis of Web of Science data

Figure 2: Physical sciences publications per million population (1996-2012)



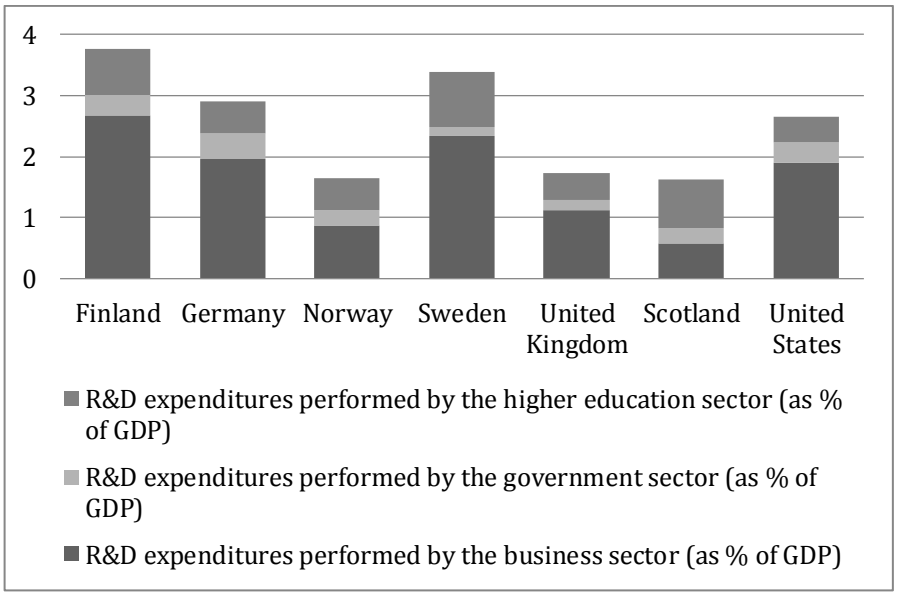
Source: Scopus database

Figure 3: Patent applications per million head of population



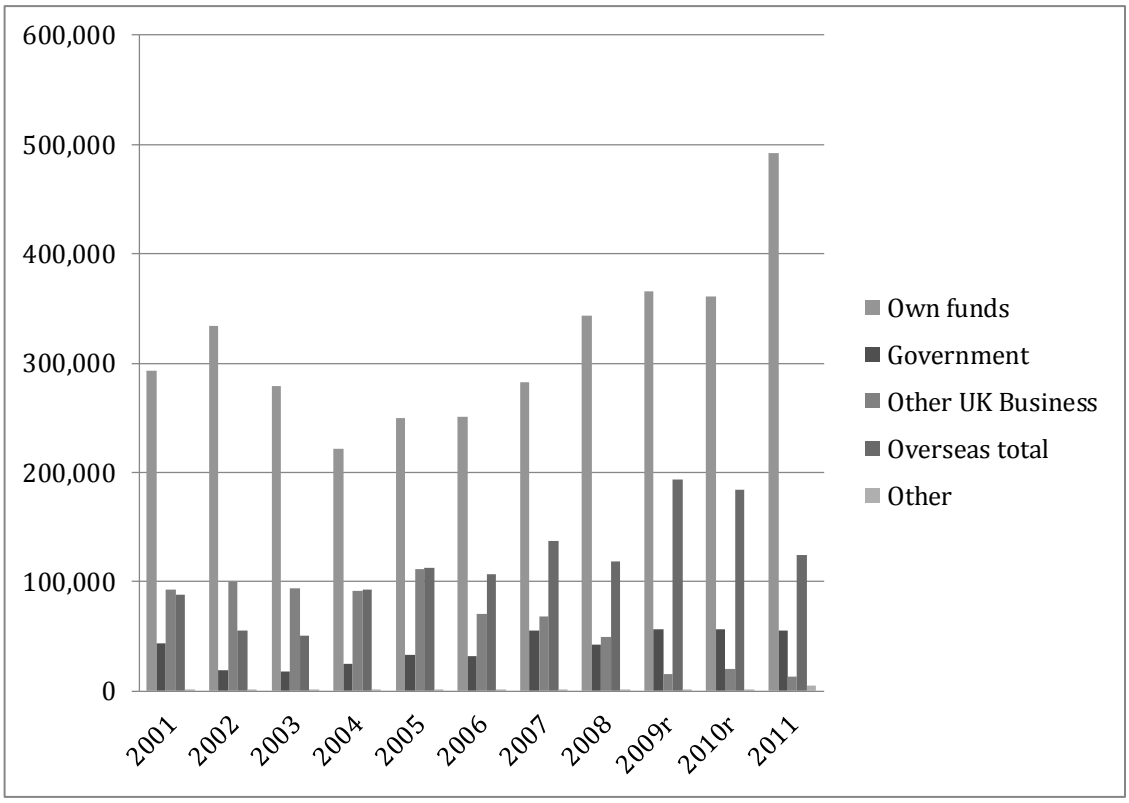
Source: OECD iLibrary

Figure 4: R&D expenditures as GDP percentage – 2011



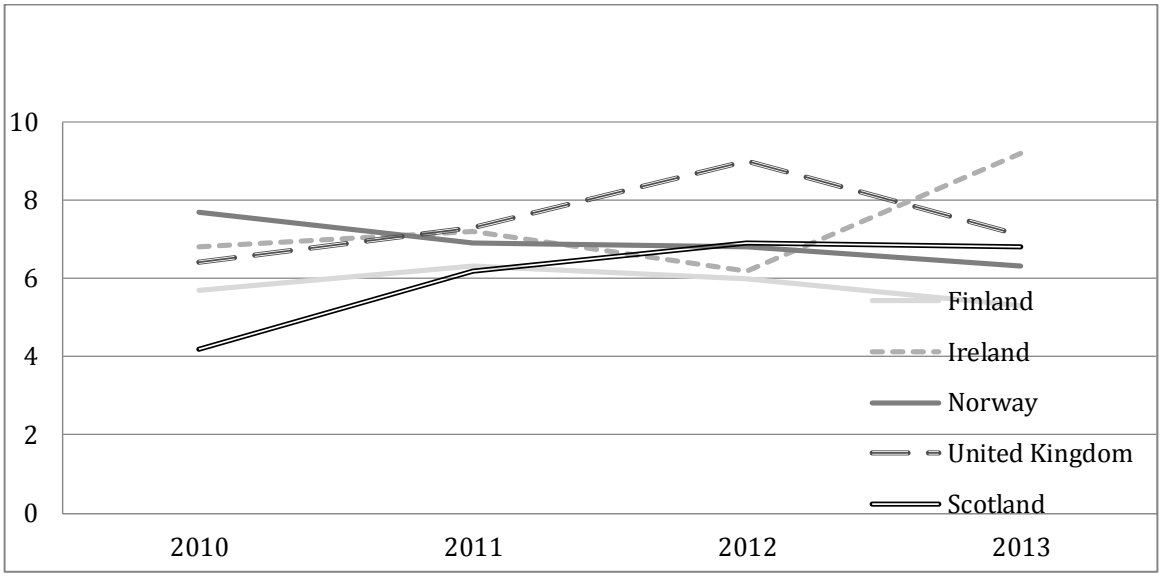
Source: OECD iLibrary

Figure 5: Sources of Business R&D in Scotland- £000s



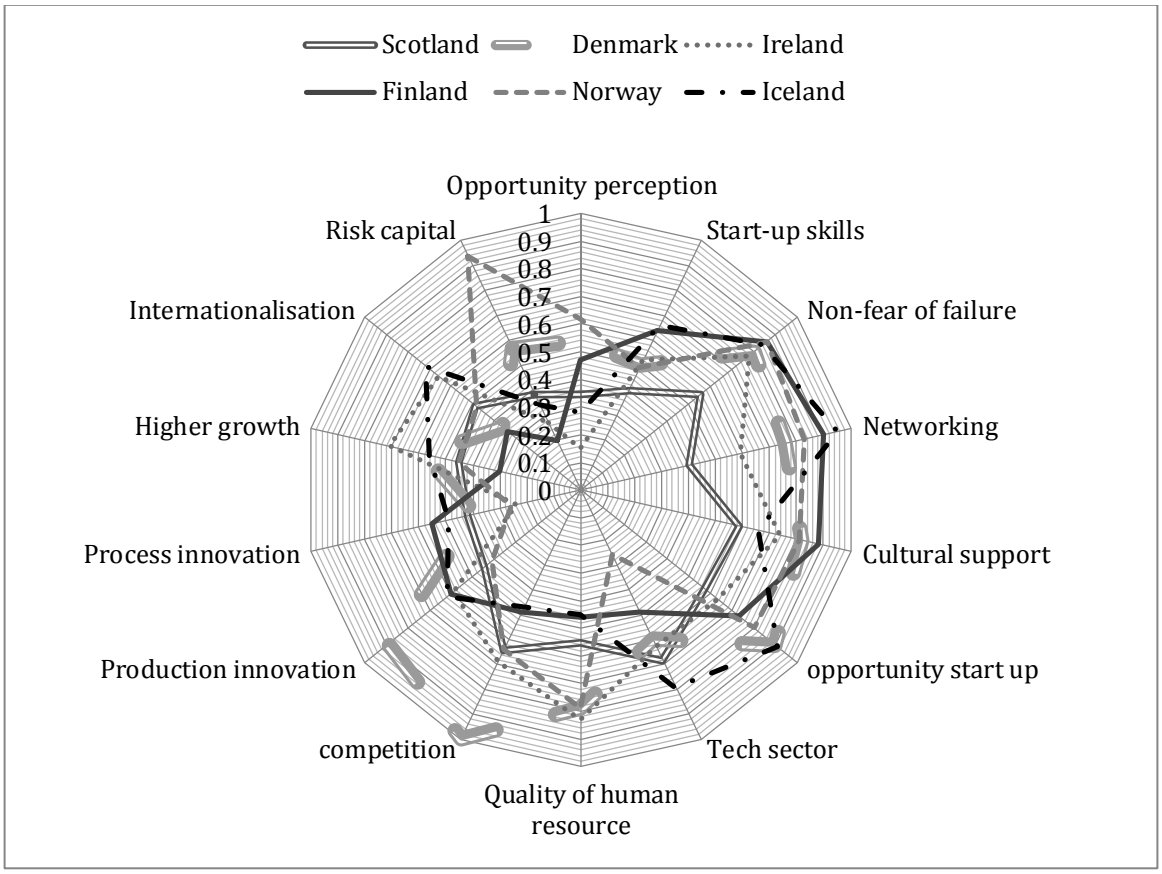
Source: Office of National Statistics
r: denotes revised figures

Figure 6: Total entrepreneurial activity 2010-2013



Source: GEM database and GEM 2013 report

Figure 7: Scotland's innovation-based entrepreneurship ecosystem compared with 'Arc of Prosperity' economies



Source: GEDI (the Global Entrepreneurship and Development Institute)- 2013 Values