Science and Industrial Dynamics in Scotland

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Introduction

This paper is intended to understand the evolution of the Scottish science and innovations systems before the Scottish independence referendum of September 2014, and the prospects for the next years. Scotland traditionally has a strong science base, with world-leading universities driving the development of science, together with a diverse range of associated research institutes, which mostly survived the Thatcher government rationalisation and privatisation of public research institutes. The science system has been strengthened during the 2000s as devolution brought a set of new and expanded funding streams into the existing UK-based institutions.

There are questions, however, about the relationship between the science base and Scotland's innovation system. Although it is neither possible or healthy to attempt to rigidly glue science priorities directly to local innovation dynamics, it is important to analyse the frameworks, policies and relationships between actors and activities to understand how Scottish scientific excellence can be exploited to improve capacities for social, cultural and economic development.

This paper first traces key elements of the historical development 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 Scottish institutions that exist to integrate Scottish science policy. It shows that the science system already operates with some, though rather limited, autonomy from the rest of the UK. This is followed by an analysis of the rather tenuous level of connection between science and innovation. Finally, it presents some thoughts on the future prospects for science and innovation post-referendum.

Background

A major report was produced in the early 1990s, which argued for increased devolution of regional science and technology, especially in Scotland (Edgerton and Hughes, 1993). It is an extremely useful and detailed document, which gives a baseline picture of the pre-devolution situation in Scotland. Indeed, the report was, it said: 'the first comprehensive review of scientific and industrial research activity in Scotland' (p1). It was also an important document from which to analyse the post-devolution period, not only from its comprehensive mapping of data but also with its policy advice and warnings. It is useful to compare its policy proposals with what has actually happened in the last twenty years, but also with the possibilities for the post-referendum science and technology future of Scotland. Its critique of the science and technology cuts of the Thatcher government – one element of the cuts that provoked a Scottish backlash against economic neo-liberalism and the UK government – went together with a warning not to focus hard down on a few chosen R&D strengths. For example, it argued for regional diversity: 'policy makers should not be seduced by the claim that future competitiveness will be determined by R&D strength in three or four key technologies' (p1), a sentient point given that, at the time, Scottish industrial R&D was highly concentrated in electronics and electrical engineering with Ferranti as the flagship company. Just a few years later Ferranti went bankrupt.

The report mapped the massive drop in government R&D in the 1980s, particularly the fall in government support for industrial R&D. But it 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 at that time. It 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[1] and 8.3% in 2013.[2] The report showed clearly that science and R&D capacity were concentrated in universities, though subsidiaries of large multinationals also did R&D toward their high value added activity. The report welcomed the proposal for a Scottish university funding system (now SFC) and argued against university selectivity and concentration. It proposed a Scottish Research Council (which is not yet a reality) and a Scottish Science Advisory Committee (which is). It called for more government funds towards industry R&D so as to create a diversified industrial R&D base.

Twenty-odd years on, it is now possible to observe significant changes to the Scottish science base and innovation system. The Scottish Higher and Further Education Funding Council (now SFC) was indeed set up and has developed some original approaches, for example:

1. A less selective approach to the research funding that comes from the periodic peer review Research Assessment Exercise (RAE), now called the Research Excellence Framework (REF). Albeit with increasing selectivity over time, there has been consistent research funding to all Scottish universities and there are no solely teaching universities.
2. A 'pooling' initiative, developed after the 2001 RAE, 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 RAE results in 2008 showed significant improvement on 2001.
3. A fund for innovative activities, which can be used to help attract big research initiatives to Scotland.
4. A set of Innovation Centres to help link Scottish research with industrial innovation. These are new from 2012, with eight centres so far (digital health, stratified medicine, sensors and imaging systems, industrial biotechnology, oil and gas, construction, aquaculture, and data lab).

In innovation there have also been some initiatives, though perhaps not so much institutional change. 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 the location of new high tech industries into Scotland. Its early success was not sustained into the 1990s as much relocated industry, for example the 'silicon glen' hardware 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 started a life science sector. SE took up a cluster development strategy and began to build networks and support structures to carry out such a strategy, which had been recommended by

[1] House of Commons, 1999, A Century of Change: Trends in UK statistics since 1900
[2] Office of National Statistics

Porter (1991). The cluster strategy aimed to build on areas of knowledge strength. These rather interventionist approaches in Scotland stood out well before devolution in 1999, and have been continued since then, though the Intermediary Technology Institutes in three cluster areas had quite a short life. SE has developed a multi-strand strategy to build skills and capabilities, and to create a funding base for new firms (refer to the working paper on innovation).

At the same time as these initiatives, there have also been major changes in the UK. The large government R&D funding increases from 1999-2010 were followed by almost level funding during the coalition cuts period. Institutionally, the Research Council UK has pulled together cross-research councils for large research initiatives, and the Technology Strategy Board has been established to build industry-research relationships. Scotland has done relatively well, perhaps the best of the ‘out of golden triangle’ locations, using multi-funding streams to build its science and innovation eco-system.

Method

To address the research questions of this project we started by examining the existing conditions for science and innovation in Scotland. This included extensive review of the literature, as well as analysing the policy documents that concerned science and innovation in Scotland. We also analysed the data for science and innovation in Scotland. In particular, 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 secondary data collection was then supplemented with information gathering from experts using interviews. The overall approach in selecting interviewees was to approach people who hold overview knowledge and experience of Scottish science and innovation, as well as practitioners positioned at the interface of science and innovation in Scotland. In total, we conducted 10 interviews. Finally, a full day workshop of invited researchers, government, and industry was held on the future of Scottish science and innovation. We ran scenarios by using 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, and 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.

Science and Innovation Actors in Scotland

Devolution has brought autonomy for the Scottish parliament and government to take decisions on a range of issues that relate to knowledge base development, research and science funding. There are a number of organisations that exclusively support research in Scotland in addition to the UK-wide research organisations. These include:

a) The Scottish Government is responsible for overviewing and allocating the budget for the economic growth strategy, which covers the research and innovation strategy, and funding policies.
b) The Scottish Funding Council (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.

c) Scottish Enterprise (SE) is the main public innovation and investment agency aiming to make Scotland a globally competitive innovative economy. Its remit is to help business to start, grow and innovate. By collaborating with academia, industry, and public organisations, SE ensures that companies access resources and markets for their growth. SE does not cover Highlands and Islands.
d) Highlands and Islands Enterprise is the economic development body providing support to businesses in the highlands and islands of Scotland. It aims to enhance regional competitiveness and the contribution to the economic growth of Scotland by creating infrastructure and networks in these areas.

In addition to these supporting bodies, Scotland benefits from the support provided by the UK-wide bodies, including:

a) The seven research councils that fund research across the UK: Arts and Humanities Research Council (AHRC); Biotechnology and Biological Sciences Research Council (BBSRC); Engineering and Physical Sciences Research Council (EPSRC); Economic and Social Research Council (ESRC); Medical Research Council (MRC); Natural Environment Research Council (NERC); and Science and Technology Facilities Council (STFC).
b) The Technology Strategy Board (TSB) is the UK's innovation agency that supports the development and commercialisation of research. TSB also runs a number of UK-wide centres including the Catapult programmes whose aim is to enable the large-scale development of technologies.
c) The Intellectual Property Office (IPO) is the body responsible for granting IP rights in the UK including patents, designs, trademarks, and copyright. A well-structured IPO is essential for enabling innovations and protecting novel ideas and Scotland relies on this UK-wide organisation.

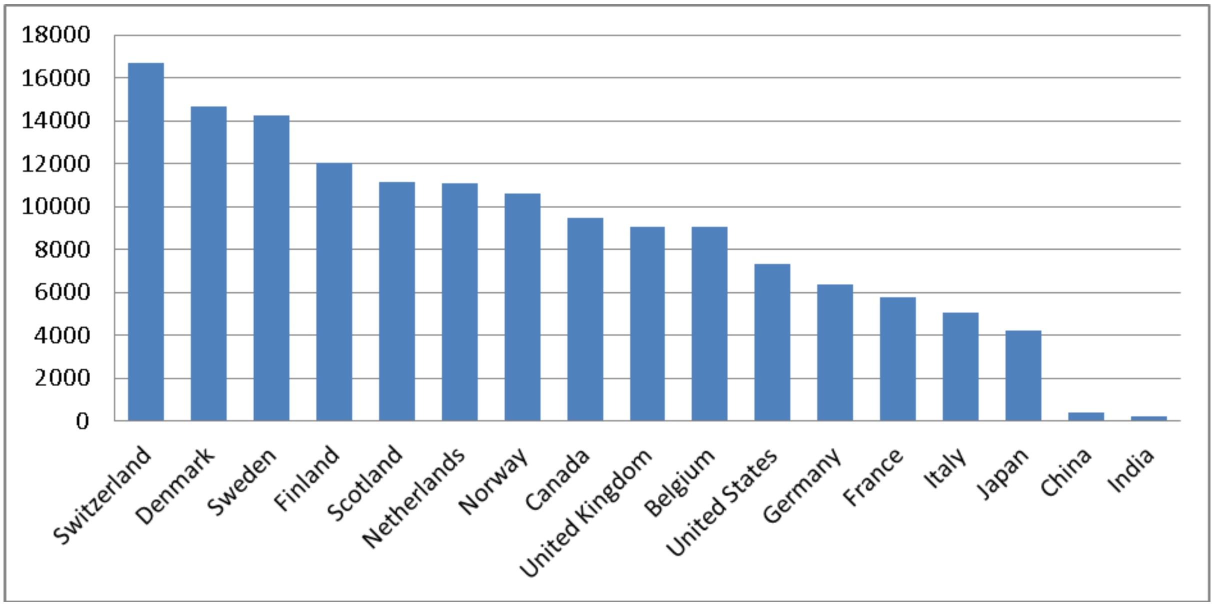
Strong Science

Publication record

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 the Scottish science base (Scottish Science Advisory Council (SSAC), 2009; The Scottish Government Office of the Chief Scientific Adviser, 2007). One of the commonly discussed output indicators for science is the publication record in a country. However, absolute numbers of publications cannot be of much value because they do not provide a baseline for comparison between different countries. Sometimes, data are produced of research per unit of GDP, but this can distort the results for countries with rather weaker GDP – for example, enhancing Scotland in comparison to richer Scandinavian and 'arc of prosperity' countries. Therefore, in order to compare research publications based on capability, we used research publications per million population as the main unit of analysis. We analysed the publication record from 1996-2012 as the main indicator of science outputs.

Figure 1 presents the publication record for life sciences in Scotland and other comparator countries during 1996-2012. We begin with the life sciences because of the reputation that Scotland holds for research in life sciences globally. As can be seen in the graph, Scotland performs very well in this area of science, though Scotland does not perform quite so well as other small prosperous European nations, such as Switzerland, Denmark and Sweden.

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



Source: Web of Science data

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

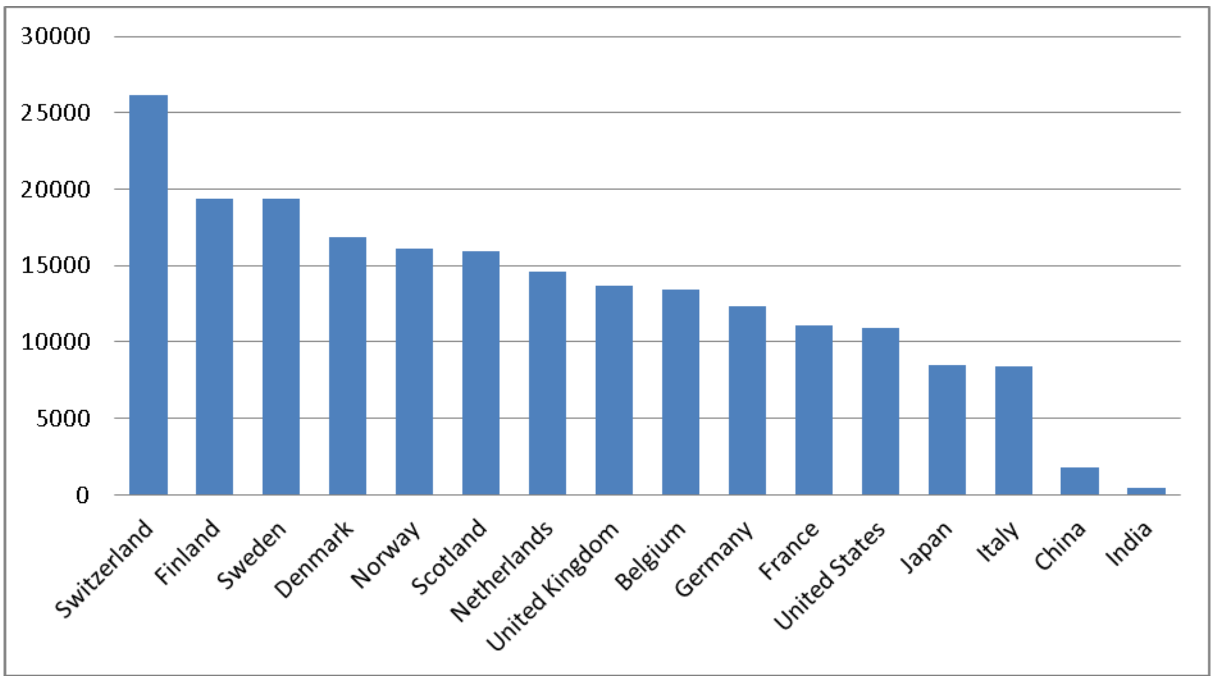
Table 1: Publications per million population in different areas of life sciences

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

Scotland's performance in physical sciences is remarkable, too. Figure 2 presents the Scotland's publication record in the area of physical sciences, Scotland ranks well compared to other successful nations.

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



Source: Scopus database

However, there is divergence between the levels of publications in different subfields. There are certain areas in which Scotland excels in terms of publications. Table 2 presents the publication record per million population different areas of physical sciences including engineering, physics and astronomy, material sciences, computer science, environmental sciences, chemical engineering, and energy. As the table suggests, Scotland's science base is stronger in physics and astronomy, computer science, chemistry, chemical engineering, and energy while it is weaker in engineering and material sciences.

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: Scopus database

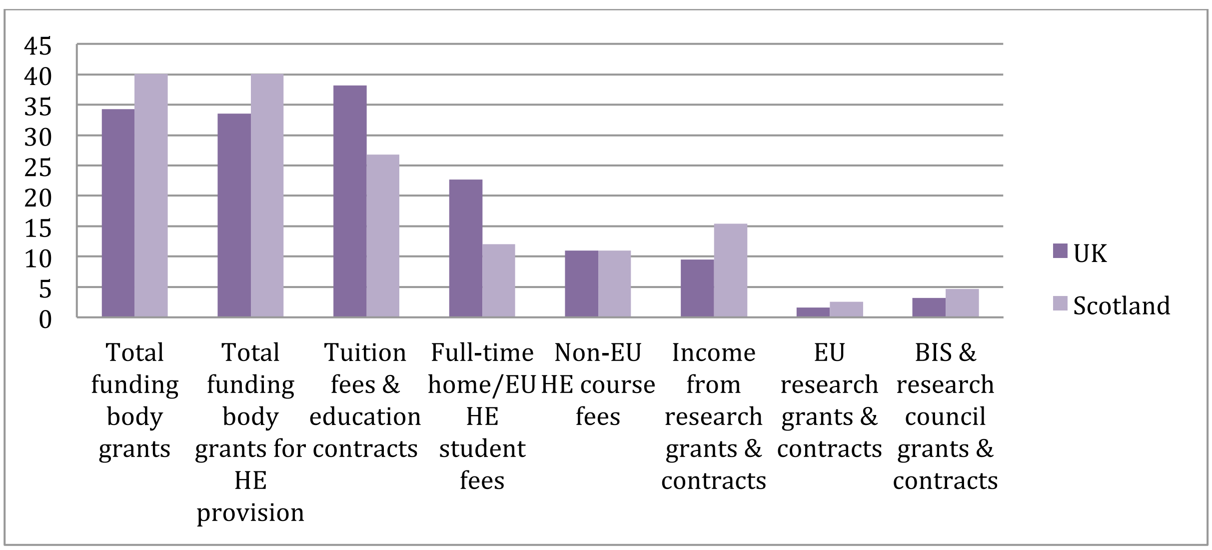
Funding structure of universities

The concept of dual support frames the UK research funding system. In the first pillar of the dual support academics compete to secure research grants from research councils based on their research quality, which is determined through the peer-review process. A second source of research funding is based on the outcomes of the Research Assessment Exercise (currently Research Excellence Framework). This acts as baseline funding to each institution and hence to disciplinary units of assessment. As for the funding which is received from research councils, Scotland receives more per head than the UK as a whole. For instance, in 2012-2013, Scottish universities' share of research council grant was 13.1% (£257million) of total UK's research council funding, which is significantly higher than its contribution to GDP (8.0%) (HM Government, 2013).
The so-called 'old' universities receive a higher percentage of research funding. In Scotland this includes the ancient universities (Aberdeen, Glasgow, St Andrews, Edinburgh) and those established as universities by the 1970s (Strathclyde, Heriot-Watt, Dundee and Stirling). As described above, to help less research-intensive universities, the Scottish Funding Council has taken the position to encourage the some funding for 'Research Quality' to all universities.

In addition to research, teaching is the other main source of income in universities. There have been many changes in policy on tuition fees over the past two decades. In 1998, tuition fees were introduced across the UK at a level of up to £1000 per year. Fees were the same for all universities, but students from less affluent families would pay less. After the establishment of Scottish government in 1999, Liberal Democrats successfully argued for abolition of tuition fees as part of their coalition deal with the Labour Party in 2000. Under this regulation, students who attended universities in the rest of the country would have to pay for their tuition. In 2001, a graduate endowment scheme was introduced in Scotland according to which all university graduates had to pay £2000 after their graduation. While in 2004, in the rest of the UK, universities were allowed to charge up to £3000 tuition fees which were repayable once students earn £15000 salaries, in Scotland, the fee system remained the same. In 2007, the Scottish government abolished the graduate endowment scheme, which meant that existing and future students did not have to pay the fee. In 2011, the tuition fee for students in England was raised to a maximum of £9000 with repayments required once students' salaries reach £21000. Scottish Government, however, decided not to charge tuition fees and to fill the anticipated gap in higher education funding through increased SFC teaching funding.

Figure 3 presents a breakdown of funding sources in Scotland and UK. As it is evident in the graph, research funding constitutes a higher proportion of income in Scotland while teaching funding in UK is a more significant source of income. The right hand columns show that the SFC does indeed give more teaching funding to universities. However, as the graph suggests, the higher ratio of research income does not compensate for the gap generated by the differences in tuition fee teaching income.

Figure 3: Percentages of research and teaching income in Scotland and UK- average values for 2011-2012



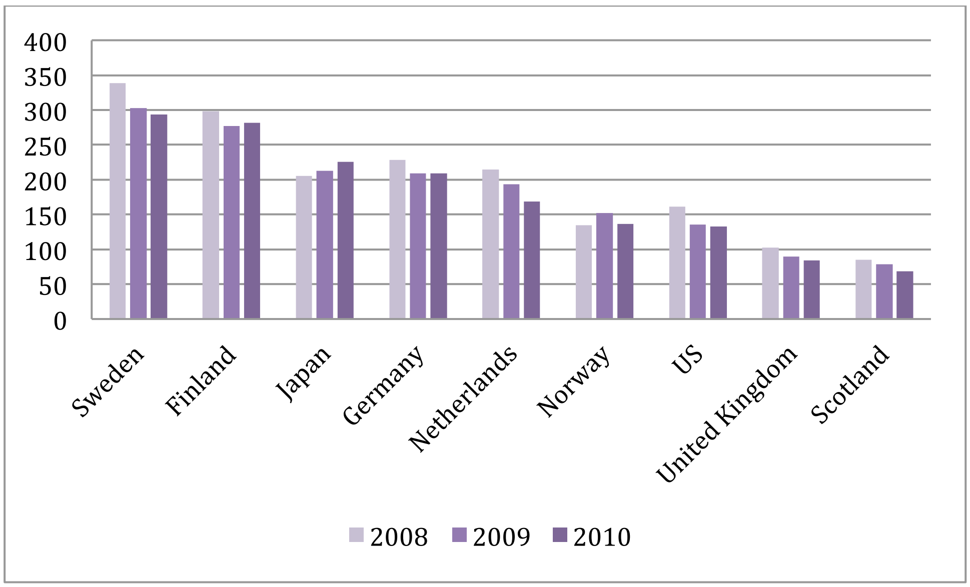
Source: Higher Education Information Database for Institutions (HEIDI)

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

Innovation measures

Despite its world-class science, innovation in Scotland is relatively lacking compared to other innovative nations (SSAC, 2009, 2013), and data suggests that the science base has not so far translated well into innovation. One of various indicators of innovation – albeit contested – is the patent record, which is relatively poor for Scotland (Figure 4). For instance, with 68.5 patents per million head of population, Scotland generates four times fewer patents than Finland (281.5 patents per million head), significantly fewer than countries like Sweden, Japan, Germany, US and (294, 226, 209, and 132.5 patents per million respectively) and even less than the UK average (with 84 patents per million).[3]

Figure 4: Patent applications per million head of population



Source: OECD iLibrary

In this research, we found a number of possible reasons for this weak relationship between science and innovation. First, research suggests that Scotland does not exploit its human capital as much as it potentially could. Scotland has 36.9% of its labour force with 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%), the highly educated labour force in Scotland has not been as significantly employed in high and medium-high technology manufacturing sectors. Scotland's 3.86% 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%).[4] In addition, there is evidence that Scotland has been notably weak in cultivating

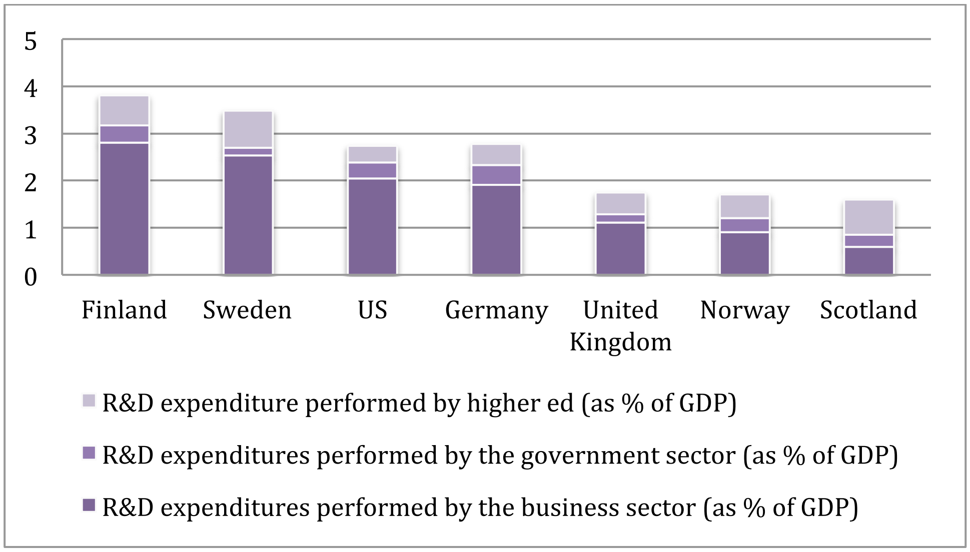
[3] OECD statistics – 2010 values
[4] OECD statistics- 2008 values

commercial and managerial skills that are critical for developing innovations out of basic science (Plany, 2010).[5] As one of our informants 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"*. There is a dearth of senior managers who are capable of running large-scale corporations and who can start big initiatives and there are not many large companies in Scotland that can attract or retain experienced managers. Therefore, there is a "*chicken and egg*" problem in that the limited number of large companies in Scotland and lack of high-level managerial skills are related. Spinouts and start-ups tend to leave Scotland and find a base elsewhere once their businesses start to grow. Dearth of 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 5), as well as lower than other regions within the UK (e.g. East and South England with 4.3% and East of England with 2.1%) in 2010. A closer look at the data reveals that this disparity is mostly driven by the lower performance of the business sector rather than higher education and government. 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 expenditures performed by businesses in Scotland (0.59% of GDP) is considerably less than other innovative countries or other innovative regions within the UK, and indeed is even less than the UK average (1.1%).[6] Thus, the business sector's lower contribution to R&D expenditure is responsible for the overall lower percentage of R&D expenditures to GDP in Scotland. The low levels of Business R&D investment calls for measures that can potentially encourage R&D investment in Scotland (e.g. through R&D tax credits, etc.), although there is no conclusive evidence that policy measures encouraging higher R&D expenditure by themselves yield innovation (cf. Köhler et al. 2012).[7] R&D measures need to be brought together within a wider sense of how the Scottish innovation system could be improved.

[5] http://www.planyscloud.com/
[6] OECD statistics – 2009 values
[7] Köhler, C., Laredo, P., Rammer, C. The Impact and Effectiveness of Fiscal Incentives for R&D. Nesta Working Paper No. 12/01: http://www.innovation-policy.org.uk/share/01_The%20Impact%20and%20Effectiveness%20of%20Fiscal%20Incentives%20for%20R&D.pdf

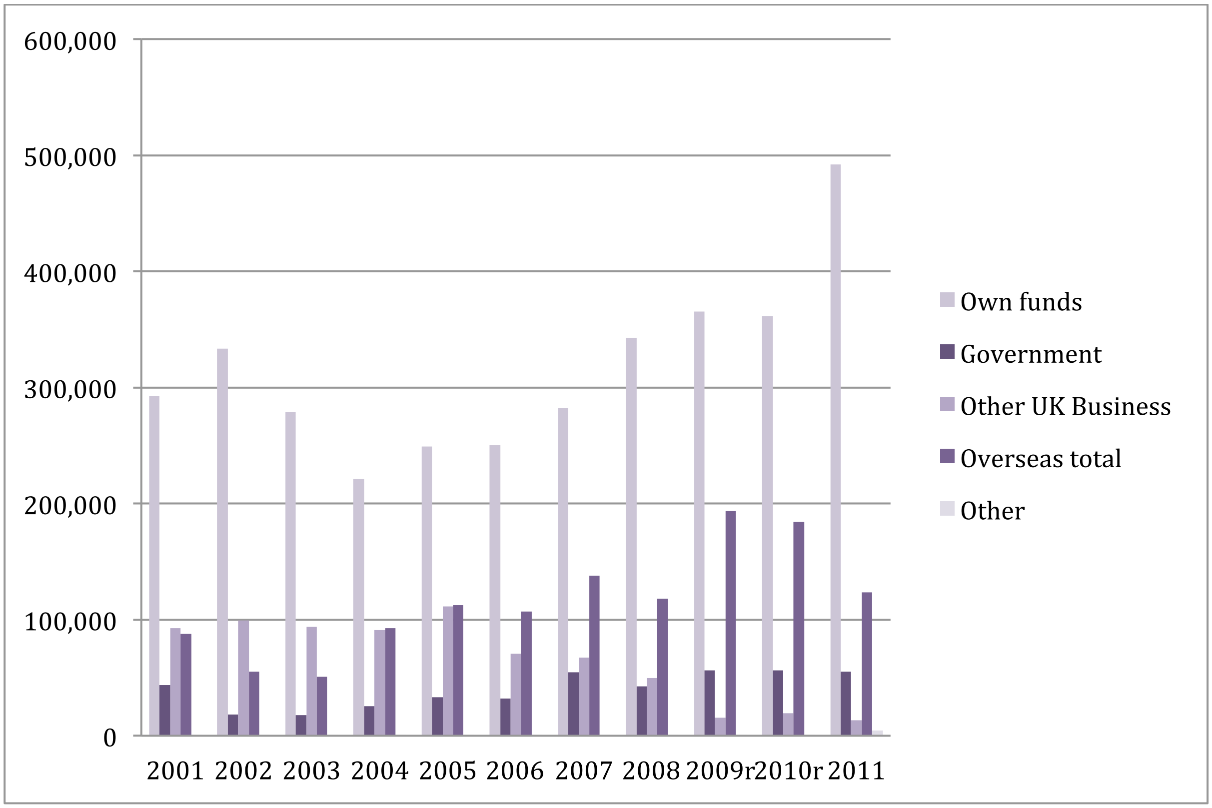
Figure 5: R&D expenditures as GDP percentage – 2010



Source: OECD iLibrary

Figure 6 demonstrates a 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 over this period, while the level of funding by other UK businesses have been significantly declining especially since 2005. Apart from a sharp drop in the level of overseas funding in 2011, this source of funding shows an increasing trend during this period. As Figure 6 indicates, the level of BERD has increased over the last decade. However, the increase in Scotland was from an extremely low base. Scotland suffers from a lower level of BERD as a percentage of GDP compared with the UK and most other regions. It presents the levels of BERD in Scotland compared to other regions, and suggests that Scotland spent less than 4% of total UK BERD in 2011. As it is clear from the two figures, Scotland has a low level of BERD expenditure relative to its size (8.3% of population and 8.0% of GDP).

Figure 6: Sources of Business R&D in Scotland- £000s



Source: Office of National Statistics
r: denotes revised figures

The risk capital market is one source for investigating business R&D expenditures. A recent report by Harris and Mason (2012) suggests that the risk capital market in Scotland has performed relatively well in the deal band size between £100k and £2 million. For instance, in 2011, £12.8 m worth of angel investment and £14.4 m of VC funds were channelled into businesses in this range (Mason and Botelho, 2013)[8]. Over the recent years, the business angel investment model in Scotland has matured and has contributed to the growth of investment by aggregating the money of high-income individuals who are less knowledgeable about the markets. However, the situation is not so good with larger venture capital investments (over £2 million). 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 downside of the limited level of VC support is that it is hard for angel investments to lead into 'companies of scale'. As one of our interviewees articulated: *"Penetrating global markets needs VC investment which is absent in Scotland".*

The small amount of available VC investment means that Scotland needs to adopt a more aggressive strategy to attract non-UK VCs and especially to engage with investors that specialise in sectors where Scotland excels. This can be achieved through making

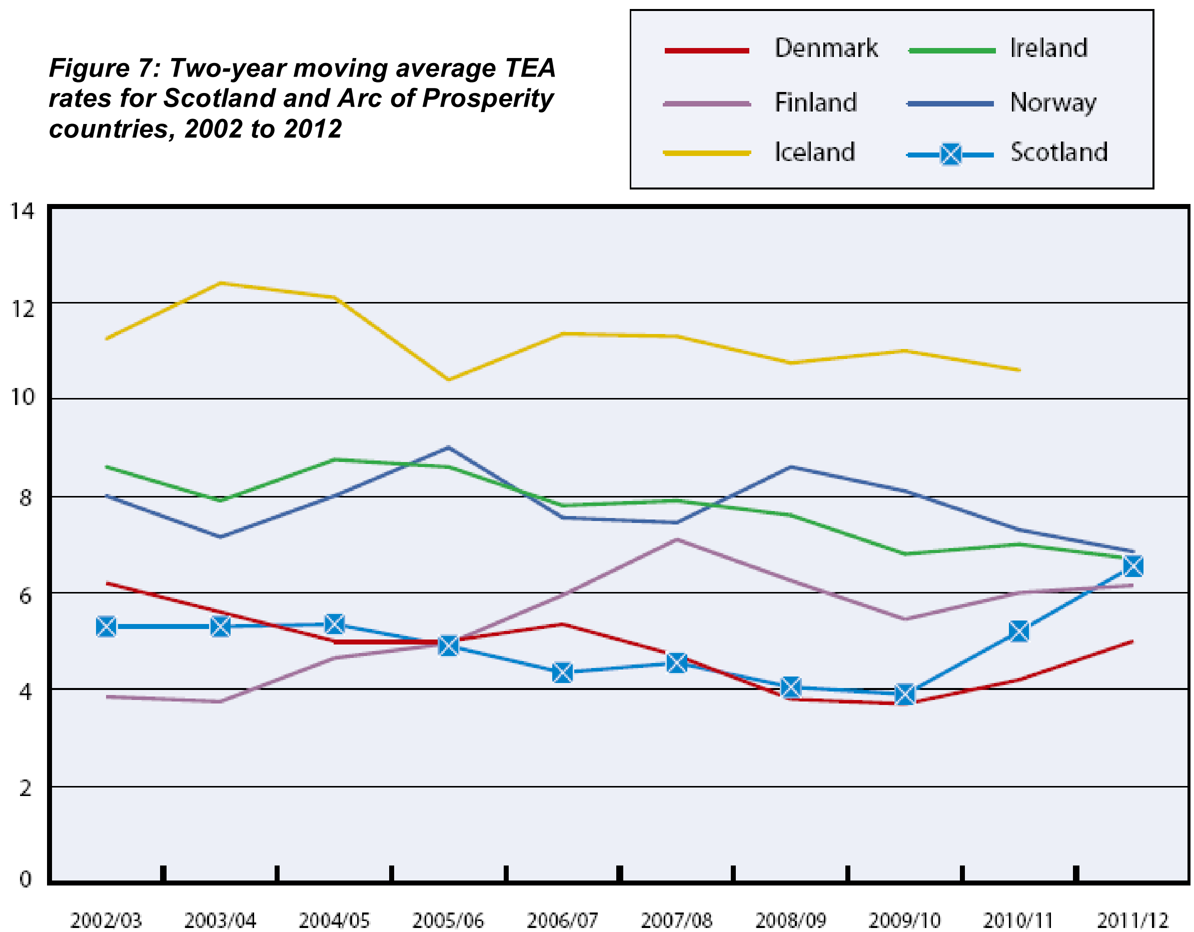
[8] Mason, C., Botelho, T. (2013) The Transformation of the Business Angel Market: Evidence from Scotland

connections with foreign venture capitalists. In the presence of increased financial uncertainties on venture capital markets, firms may require consideration of alternative funding models and/or strategising effective management of demand markets, which highlights the role of accelerators and soft funding methods such as crowd funding, lean start-ups, and bootstrapping become more important (Harris and Mason, 2012).[9]

Entrepreneurial activities

BERD funding usually comes from enterprises that are large enough to afford to invest in dedicated R&D. However, innovation is also driven by entrepreneurial activities in small and medium size enterprises. Entrepreneurial activities and aspirations are known to be a driver for innovation in innovative countries. 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. As Figure 7 indicates, among the Arc of Prosperity AOP countries, Finland and Denmark show signs of increased TEA. As the table suggests, the TEA rate in Scotland grew by 11% from 2011 to 2012, which is lower than the UK but higher than the other comparator countries.

Figure 7: Two-year moving average TEA rates for Scotland and Arc of Prosperity countries, 2002 to 2012



Source: GEM report, 2012

[9] Harrison, R., Mason, C. (2012) The Risk Capital Market in Scotland 2009 – 2011

There are a number of factors that contribute to entrepreneurial activities. In their ranking, the Global Entrepreneurship and Development Institute (GEDI) measures the innovation drivers in two dimensions: a) activity; and b) attitude and aspiration; dimensions which consist of 14 pillars (cf. Annex-1 for a full description of the pillars). As Figure 8 suggests, in comparison with other 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 tech sector, competition, opportunity start up, and cultural support. In general, the figure suggests while Scotland does well in some activities, it is lacking in the areas that relate to attitudes and aspirations.

The ability to collaborate across organisational and disciplinary boundaries is known to contribute to innovation. However, as shown in Figure 8, Scotland is not particularly strong in forming and harnessing collaborations and networking (Levie, 2012).[10] For example, lack of collaboration between companies and academia can decrease the capacity of companies to acquire and absorb knowledge from academia and each other. According to our informants, the UK research evaluation exercise (RAE/REF) was seen as weakening the relationship between academia and industry because of its emphasis on academic publications rather than engagement with industry, which leaves little incentive for academics to collaborate closely with industry. Moreover, Scotland has not been very successful in establishing lucrative clusters which are critical in creating critical mass and enabling innovations. Clusters are important as they generate economy of agglomeration, and make pools of resources available to firms. Therefore, complementing the current REF system with incentives for academics to collaborate with industry, encouraging the formation of clusters and meta-clusters within Scotland, and facilitating internationalisation of Scottish companies are potential paths for reinforcing the innovation base within Scotland.

[10] Levie, J. (2012). Global Entrepreneurship Monitor: Scotland. Glasgow: Global Entrepreneurship Monitor.

Figure 8: Scotland's innovation-based entrepreneurship ecosystem compared with 'Arc of Prosperity' economies

Source: GEDI (the Global Entrepreneurship and Development Institute)

In conclusion, TEA rates increased strongly in the UK and Scotland in 2012. Despite the increase in TEA rates in Scotland, its entrepreneurial activities remained significantly behind the UK. Scotland's TEA rate is close to that of AOP countries and average of innovation-driven countries, which is a significant development since the financial crisis. However, entrepreneurial activities in Scotland have been limited to aspirations of recruiting less than five employees in start-ups which signals lack of aspiration for high-growth companies (Levie, 2012).

Science-innovation 'disconnect' and the independence debate

The evidence on academic-industry collaboration is only one part of the picture. The independence debate might provide an opportunity to move from the traditional argument that in Scotland 'science is good, innovation is weak' towards a more integrated innovation systems approach. The traditional 'science good, innovation weak' approach often leads to 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. One recent example of such an initiative has been in the food and drink sector (Interface

Food & Drink). This begins from the needs of the industry, a key and internationally successful industry in Scotland rather than from what is good about Scottish science. It was not the aim of this research project to determine whether independence will enhance or hinder science and innovation in Scotland. Irrespective of the outcome of the referendum, Scotland needs to understand how its scientific excellence can be exploited to its maximum capacity (SSAC, 2013). We aimed to reveal the dynamics in the science/innovation system in Scotland, which in turn enables a better understanding of the consequences of a Yes/No scenario. Therefore, using the insights we developed through this research, we developed a scenario for the implications of a “yes” vote for science and innovation (Figure 9). We assumed that a “No” vote would mean retaining the status quo. So our scenario mapping is mainly formulated around the “yes” vote and its associated opportunities and risks.

Regarding the future of science and research the UK government and Scottish government have published two rather different papers detailing what would happen after independence. In a report published in November 2013, the UK government warns that independence would mean the abolishment of the “integrated research system”, which would mean that Scotland will have to build its own research system (HM Government, 2013). The Scottish Government independence white paper adopts a different approach and argues for retaining the integrated current research system that it refers to as the “common research area”. The white paper argues that retaining the common research area is in the interest of scientists across the border.[11]

Under the independence scenario, Scotland and the rest of the UK may either continue to operate in a single research area or their research will separate. The latter case means that Scottish universities may lose their access to the disproportionately high funding that they enjoy at the moment. More importantly, the abolishment of the single research area can negatively affect collaboration between scientists across the borders. A range of other changes would include the need for international peer review in Scotland to address the small size of the research community. The process for REF, the second pillar of research funding in universities, would need to change in a similar way. Independence could drive existing businesses in Scotland to move to the South to protect their asset value (if they fear it may decline due to the uncertainty created by independence).

On the other hand, the abolishment of the single research area would create opportunities for systematic change in the way research and innovation are supported. For example, a common theme in our findings was the excessive focus of Scottish universities on scientific publications limits the applicability of their research output and discourages university-industry linkages. A revised system could attempt to address that ‘disconnect’. Another lever that independence could bring to Scotland is to attract larger and medium sized enterprises with R&D activities. An independent Scotland would have the fiscal power to reduce the corporate tax and grant R&D tax credits to attract R&D intensive companies. However, the headquarters of large companies do not always move to regions with lowest tax, as their success is equally reliant on the availability of the skills and resources required for excelling. Therefore, it would be naïve to think merely employing fiscal policy would attract large companies to Scotland.

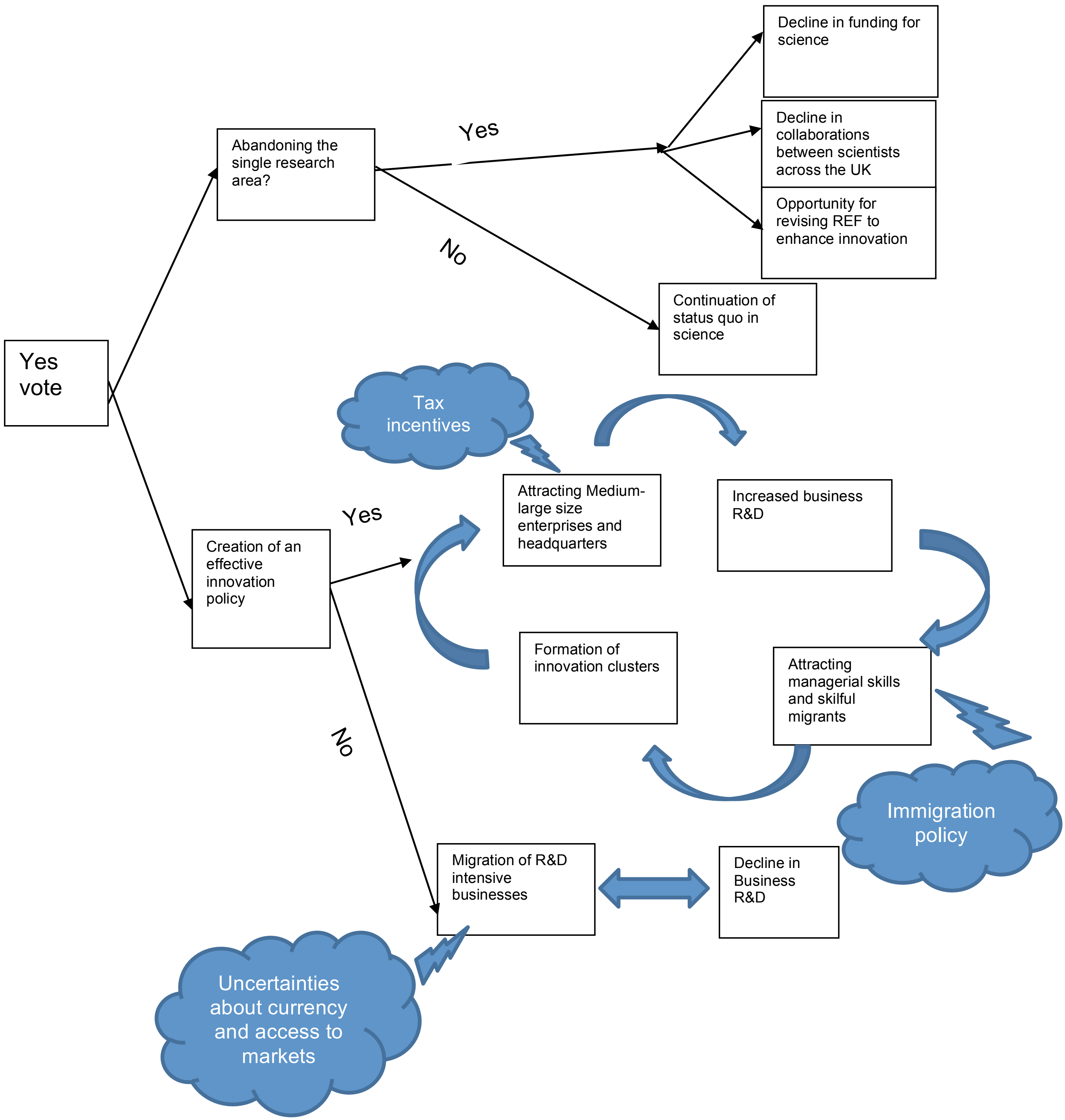
[11] Please see: http://www.futureukandscotland.ac.uk/blog/science-research-and-scottish-independence for further information.

In summary, there is a strong concentration of high quality research in Scotland. However, the linkages between the science base and innovation are not strong. There is rather weak use of Scottish universities by Scottish based firms and the absorptive capacity in local business is quite weak.

It is our contention that 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. Such an approach would necessarily involve an integrated raft of activities and institutions focused on existing and emerging industries and services.

This is a medium to long-term approach, of course, with few 'easy wins'. However, such an approach will improve the prospects for structural changes in the Scottish economy to make it more innovative.

Figure 9: Risk and opportunities for science/innovation under independence scenario



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Appendix-1

The Description of the Individual Variables Used in the GEINDEX

OPPORTUNITY The percentage of the 18-64 aged population recognizing good conditions to start business next 6 months in area he/she lives,

SKILL The percentage of the 18-64 aged population claiming to possess the required knowledge/ skills to start business

NONFAIRFAIL The percentage of the 18-64 aged population stating that the fear of failure would not prevent starting a business

KNOWENT The percentage of the 18-64 aged population knowing someone who started a business in the past 2 years

NBGOODAV The percentage of the 18-64 aged population saying that people consider starting business as good carrier choice

NBSTATAV The percentage of the 18-64 aged population thinking that people attach high status to successful entrepreneurs

CARSTAT The status and respect of entrepreneurs calculated as the average of NBGOODAV and

TEAOPPORT Percentage of the TEA businesses initiated because of opportunity start-up motive

TECHSECT Percentage of the TEA businesses that are active in technology sectors (high or medium)

HIGHEDUC Percentage of the TEA businesses owner/managers having participated over secondary education

COMPET Percentage of the TEA businesses started in those markets where not many businesses offer the same product

NEWP Percentage of the TEA businesses offering products that are new to at least some of the customers

NEWT Percentage of the TEA businesses using new technology that is less than 5 years old average (including 1 year)

GAZELLE Percentage of the TEA businesses having high job expectation average (over 10 more employees and 50% in 5 years)

EXPORT Percentage of the TEA businesses where at least some customers are outside country (over 1%)

INFINVMEAN The mean amount of 3 year informal investment

BUSANG The percentage of the 18-64 aged population who provided funds for new business in past 3 years excluding stocks & funds, average

INFINV The amount of informal investment calculated as INFINVMEAN* BUSANG