Introduction

The Royal Society of Edinburgh’s Foresight Seminar series focuses on sectors of significant economic importance to Scotland with the aim of improving R&D interactions between universities, SMEs, and larger companies. The longer term goal is to encourage greater R&D investment in businesses located in Scotland to the benefit of the local economy. This investment could be support of appropriate research in universities and research institutes; integration of research within existing corporate functions in Scotland; or establishment of stand-alone research centres.

The seminars, supported by Scottish Enterprise, SHEFC and RSE, were inspired by the national Foresight programme, and by the “Commercialising the Science Base” enquiry, both of which aim to improve the focus of R&D resources on wealth creation. The following outline agenda is generally followed:

- Chairman’s introduction.
- A keynote presentation by a senior representative of a large multinational company on technological and market trends within the selected sector.
- An overview of related research within Scottish universities and research institutes by a senior academic.
- Dinner discussion on predetermined topics related to the sector.
- Plenary discussion on presentations and topics.

The Seminar

The first seminar addressed the Scottish semiconductor industry. It was held at the RSE on February 18, 1997, and was well attended by an invited audience consisting of seventy senior representatives from SMEs, larger companies, academia and government, with an approximately equal split between these groupings.

Dr David Milne, Managing Director of Wolfson Microelectronics and RSE Vice-President, chaired the meeting and gave brief perspectives on RSE’s involvement in Technology Ventures and on the Scottish semiconductor scene.

Dr Bertrand Cambou, Senior Vice-President and Director, Sector Technology, Motorola Corporation gave the keynote talk on semiconductor technology and market trends. This very well received presentation gave a panoramic view of the semiconductor business. Highlights included:

- The world-wide semiconductor industry experienced a 16% compound growth rate through the 1990s. World-wide revenue for semiconductors in 1995 was $150 billion.
- By the year 2000 semiconductors will account for 25% of world-wide electronic equipment revenue.
- New semiconductor facilities in the twenty-first century will cost of the order of $5 billion - up from, say, $1 billion today. Significant technology advances are required in areas such as photolithography, electronic packaging and electronic materials.
- Sensor technology is a major growth area.
- There is a growing need for software specialists in semiconductor research and development. For example, Motorola’s split between hardware and software engineers and technologists changed from 95:5 in 1990, to 50:50 in 1996.
- Motorola locates its internationalised R&D function in numerous countries (including Scotland) depending on business needs and availability of unique skills and expertise.

Professor Jim Cairns, Professor of Microelectronics, University of Dundee gave a stimulating account of semiconductor research in Scottish universities, covering significant contributions on device structures, materials, processes and photolithography. He summarised activities at recently established electronic centres - e.g. EMC, ScotSense, NMI, MIAC, and SEMC - and described successful fabless university spinouts such as Vision and Wolfson Microelectronics. While the focus of this talk was on semiconductors as they relate to microcircuits, Professor Cairns described some of the progress being made in related fields such as nanotechnology, microengineering, and optoelectronics. These growth areas will be addressed in future Foresight Seminars. Professor Cairns interspersed his presentation with illuminating and amusing cameos on the historical background to microelectronics.
Feedback from Foresight Semiconductor Discussion Groups

A list of points generated during the dinner discussions and discussed further during the plenary session are summarised below under the broad headings of Corporate R&D investment in Scotland, emerging technologies and markets, the role of SMEs, and Scotland’s future in the semiconductor industry. The discussions were clearly wide ranging and raised a number points, some of which are specific to semiconductors and others of cross-sectoral relevance.

R&D investment in Scotland - points from discussions

- Scotland’s existing provision of support to foreign direct investment (FDI) is not sufficiently cohesive to encourage companies to locate here.
- Information flow is a problem especially when dealing with overseas companies.
- Scotland must stop acting locally and think globally - we plan too small.
- FDIs must be made aware of the wealth of skills in Scotland. This includes support for design and not just manufacturing skills.
- Talent and new technologies are needed in order to encourage R&D investment.
- Key criteria are skills and values of people.
- Scotland has a small talent base.
- Multinationals are moving to the most favourable tax countries. Tax incentives attract value-added jobs (c.f. Israel).
- Universities are getting better at doing near market research.
- Large corporations should encourage increased collaboration with universities on near to medium term research through direct funding and Research Council grants applications.
- Publicise the development, design and innovation which takes place in multinationals. They are not just “screwdriver” plants.
- Enhance the image of engineering as a career. Take long term view to encourage children to become engineers.
- Employ Scottish graduates.
- What encourages multinationals to invest in R&D?
  - conglomerations of research institutes
  - conglomerations of skills
  - focused research

Comments:

Of particular importance to the theme of these seminars is the need to understand what motivates FDIs to make inward investments in R&D and the need to ensure that Scotland’s capability to respond to these motivations is well understood. The points noted above give a flavour of the discussion. The following are some general observations on multinationals and R&D internationalisation data from The European Economy, C M Dent (Routledge, 1997).

- European multinationals are more likely than the USA or Japan to source R&D functions outside their home country. This table gives an estimate of international R&D employment for various countries as a percentage of total R&D:
  - Switzerland 40%
  - UK 18%
  - France 15%
  - Germany 7%
  - USA 6%
  - Japan 2%
Companies will internationalise R&D if it is beneficial to their organisation. A number of potential benefits were discussed at the seminar. These should be put in the context of recent studies which suggest the following motivations for R&D “dispersal”:

- More effective coupling between R&D and other corporate functions (e.g. manufacturing).
- Improved focus of R&D on business needs.
- Availability of scarce research talent.
- Interactions with localities that possess relevant technology leadership.
- Access to key technology or product suppliers or customers.
- Ability to design products for local market needs.
- Availability of government incentives.

A recurring theme throughout the seminar was that Scotland performs more R&D within the semiconductor industry than is generally recognised. It is not always easy to delineate R&D from other functions within an organisation and it is important both for the image of the industry and for future R&D investments to make sure that the current situation is clarified. Available statistics indicate that there is a deficit in industrial R&D investment in Scotland.

- Scotland’s business expenditure on research and development (BERD) across all sectors is low based on national and international comparisons:

  BERD, % GDP
  
  UK 1.4
  Scotland 0.4
  Norway 0.9
  Sweden 2.1
  Switzerland 1.9

  *The data for Scotland and the UK refer to 1994; the data for the other countries (selected for comparison because of their geographic and population similarity to Scotland) refer to 1992.*

- It has been estimated that there were approximately 2000 people involved in R&D within the electronics and electrical sector in Scotland in 1992. This corresponds to an investment of ca. £120 million per annum. This is 5% of the 1992 UK R&D expenditure of £2.4 billion whereas the expectation based on relative manufacturing value added from the sector is 9%.

- Five of the top twenty companies, based on investment in electronics and electrical R&D in the UK, are US multinationals with significant manufacturing activities in Scotland. Their total R&D investment within the UK was ca. £300 million in 1992. It is not clear how much of this was invested in R&D in Scotland.

**Technologies and Markets - points from discussions**

Key technology areas are those identified by Dr Cambou:

- lithography below 0.1 micron.
- electronic packaging e.g. multichip modules.
- new materials and processes e.g. copper structures for interconnect.
- software: simulation and modelling.

New market and applications opportunities include:

- Sensors and actuators.
- Displays. e.g. spatial light modulators, TFT-LCD.
- Nanotechnology, microengineering.
- Batteries.
- Optoelectronics.
- Biological applications.
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- Software.
- Environmental, medical, automotive markets.

Scotland needs a process research capability e.g.
- A high powered Scottish mini-fabrication facility.
- Enhance Edinburgh University’s fabrication capability.
- A Scottish version of Fraunhofer laboratories.
- Commercial applied research centres e.g. incubators.

Comment:
The discussions on future technology and market opportunities endorsed Dr Cambou’s views. It is encouraging that these opportunities (which include sensors, microengineering, nanotechnology, Optoelectronics, and lithography) are being actively addressed by a number of university research groups. In some instances they have established reputations for international excellence, not only in local opinion but through the recent research assessment exercise. Semiconductor-related research within universities takes place in many different departments which makes it difficult to judge the overall quality and extent of research within this sector. It is heartening that the average Scottish RAE ratings in electrical and electronic engineering and in computer science, two departments closely related in different ways to the IT industry, exceeded UK average RAE ratings. Edinburgh University achieved a 5* rating in E&E engineering and Glasgow University a 5* in computer science.

Several discussion groups identified the need for a Scottish research fabrication facility. This came in a number of guises including upgrading the Edinburgh University microfabrication laboratory, establishing a laboratory along the lines of the German Fraunhofer Institutes, and constructing a dedicated state-of-the-art mini fabrication capability. It was not clear who might fund such an activity. Possibilities include support from the Research Councils, SHEFC and future Foresight Challenges. A pan-Scottish industrial-academia collaborative proposal for an advanced fabrication facility would maximise the opportunity for success. The relationship of such a capability to the National Microelectronics Institute would have to be taken into account. The original Foresight recommendation from the IT&E panel called for a Microelectronic Institute with a focus on research, advanced development and support services, with a major charter in education and training. The panel recommended that this centre must have the capability of implementing key parts of the fabrication process capability. The NMI, located at Heriot-Watt University, will be a “virtual institute” and while its establishment is a major step forward for the UK semiconductor industry it will not meet this latter requirement.

The role for SMEs - points from discussions

Potential SME roles include:
- Contracted out Design.
- Exploit ideas as a fabless facility (cf. Vision).
- Develop differentiating products/services.
- Service large companies (e.g. recycling, individual process steps, specialist chemicals).

SMEs need support:
- Improve FDI-awareness of SME capabilities and hence encourage beneficial links.
- Encourage large semiconductor companies to release staff to be non-executive directors of SMEs.
- Build on Teaching Company scheme and Connect to increase innovative ability of SMEs.
- Clarify the assistance which HEIs can offer SMEs.
- Public support should be given to smaller companies to enable them to grow and move up the value chain.

But:

- The critical mass of SMEs is not a major factor in attracting multinationals - they are big enough to go overseas for suppliers.
- Plant investments approaching $5 billion rules out whole-process fabrication as a way for SMEs or universities to be involved in the semiconductor industry.
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Comment:

The two major opportunity areas identified for SMEs were service functions to large companies and design activities. The former opportunity was encapsulated by written input from the managing director of a major inward investing semiconductor manufacturer prior to an earlier meeting in Glasgow, 1994 on “Technology Foresight - the Scottish Dimension”. He stressed the importance, with reference to competitiveness and business expansion, of encouraging small and medium sized companies to supply the manufacturers with production equipment, high-tech materials (gases and chemicals), and advanced automation systems for production control.

Design potential can be developed by contract design to large companies or by exploiting good ideas as a fabless company (fabless implies that the company has design expertise but not processing capability. The latter is performed at a silicon foundry.) The fabless approach can result in very high value add but is dependent on the ability to identify market opportunities. Good local examples are Vision - the integration of image sensing and processing functions on CMOS chips - and Wolfson Microelectronics - custom designed integrated analogue circuits.

Scotland’s future in the semiconductor industry - points from discussions

- In order to maintain market share Scotland would need to open three semiconductor plants annually. The cost of entry to new microprocessor and memory fabrication plants is prohibitive and consequently the current rate of growth is unlikely to continue.
- Concentrate on other promising, related areas such as optoelectronics where growth potential is higher. Focus on a few strategic goals and gain a reputation for excellence.
- Support the strategic goals of large companies but long term strength will not come from a total reliance on FDIs. Strategic business and product decisions are taken at overseas headquarters.
- Can’t pick winners - create the right environment. Build on our R&D capabilities in industry and universities. Aim to be No. 1.
- In order to succeed, Scotland requires indigenous product R&D and product ownership. Manufacturing-only makes you vulnerable. Manufacturing is at the end of the chain. Most of the value is in design. This is certainly true of software.
- Encourage transition from research to start up. Help grow indigenous companies.
- Identify research strengths with commercial potential and skew SHEFC and Research Council funding to these strengths and hence attract private funding.
- Improve the interchange between universities and industry. This includes improving the HEI structure to allow support of long term cross links and making it easier for academics to take sabbaticals.
- Indigenous companies are important at the design level.
- Build up the supply infrastructure.
- Address the growing skills shortage, especially for experienced semiconductor engineers.
- Improve the quality of graduates; attract more foreign students and persuade them to stay.
- Need capital investment by government to attract industry.
- Emphasise networking and multidisciplinary approaches.
- Clarify and disseminate information on Scottish R&D in industry and universities.

Comment:

Taking Scotland’s dollar output of semiconductors as 10% of European output, and European output as 20% of global production, the 1995 revenue which Scotland generated from semiconductors was $3 billion. If the industry sustains the 90’s average annual growth rate of 16% (as predicted), and Scotland maintains its current share of the global market, annual revenues will amount to $24 billion by the year 2010. This calculation needs only to be approximately correct to indicate the long term importance of the semiconductor base to the economy, especially when it is noted that most of the produce is exported.

Growth in the semiconductor industry is fuelled by R&D and capital investment. For example, between 1980 and 1992 USA companies invested 12% of revenues on R&D and 14% on capital. Capital investment can be even higher in some of the “tiger” economies, who are also increasing their R&D activity with a strong focus on the electronics sector. The challenge is to maintain market share in this highly competitive, investment driven environment. Some attendees were pessimistic about Scotland’s prospect of doing this and suggested
alternative routes, such as concentrating on other growth areas such as optoelectronics. In particular, the investments required to build the fabrication facilities for the 21st century were regarded as being prohibitive - $5 billion compared with £1 billion today. This rate of increase in facility costs is not unprecedented. The cost of a typical DRAM facility was only $400 million in 1990. Additionally the ratio of facility cost to revenue may well decrease if current growth rate projections are sustained.

Whichever route Scotland takes - maintaining semiconductor market share or branching into new areas - the points made by the meeting attendees underwrite the importance of increasing indigenous R&D; creating new companies with significant design content; improving the supply infrastructure; addressing the skills shortage; improving the supply of trained graduates; and emphasising networking and multidisciplinary approaches.

Acknowledgement

This first Foresight Seminar was very well received by the meeting attendees. RSE, Scottish Enterprise and SHEFC would like to thank Dr Bertrand Cambou for his outstanding contribution during which he gave an expert and frank description of trends within the semiconductor industry, and Professor Jim Cairns who presented an informative and entertaining summary of semiconductor research in Scottish Universities. Dr George Bennett is thanked for volunteering Motorola’s support of this event, as is Ian MacFadyen, who gave invaluable technical help and advice.