National Microelectronics Institute

The UK Semiconductor Industry:

How Can A Trade Association Support A New Strategy For UK Competitiveness?

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Carried out on behalf of
The National Microelectronics Institute

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1.0 Executive Summary

This study has sought to answer the question: *How Can A Trade Association Support A New Strategy For UK Competitiveness?* Primary and secondary research has been undertaken to provide answers and insight together with industry analysis to aid a better understanding of the wider environment and industry contexts.

1.1 Industry: Context and Analysis

The semiconductor industry operates in a global environment and is extremely competitive with aggressive competition between companies in all market areas (3.5.5).

The industry is made up of a number of strategic groups that vary to degree according to vertical integration. The salient groups are characterised by their business model and generally fall into one of the following groups: Integrated Device Manufacturer (IDM), Fablite, Fabless, Chipless and Design Services (Section 3.3). Scale of revenue income follows a similar order with Intel being the largest IDM accounting for approximately 15% (estimated at $27 billion) of industry revenues in 2003 (3.4).

Significant trends include a general 4-year business cycle (3.1.2) together with continuous technological advancement and change (3.1.1, 3.1.3).

The UK has three main regions for semiconductor activities: Silicon Gorge (Bristol and South West), Silicon Glen (Scotland), Silicon Fen (Cambridge) with manufacturing presence in South Wales and the North East of England. Despite the distance to their customers, UK companies have been successful by participating at favoured locations within the supply chain. The need for close customer proximity is not imperative in global technology markets with sophisticated business customers. This has been demonstrated with the success of ARM, a UK based Chipless company and Israel, a commercially successful, technologically advanced region distant from the major market of the United States (3.6.3, 4.2).

The UK (and Europe in general) has a culture of secrecy (6.3.4). The UK has a relatively large number of design services companies (3.6.3). The perceived lack of ambition amongst UK semiconductor companies is largely accredited to risk aversion, poor commercialisation skills and other cultural factors (6.3).

Within the UK context, a SWOT analysis can be summarised as (3.7):

- Strengths – strong application skills in selected markets

- Weakness: lack of clusters, lagging productivity, skills gap/falling numbers of technical graduates, low concentration of successful industry executives
- Opportunities: application of technology to global markets
- Threats: lower cost regions of the world gaining competitive positions, not exploiting strengths effectively through slow or late responses

1.2 The Importance of Networks and Institutions

Productivity is of primary importance for determining the economic performance of a nation. Productivity is driven by forces of competition and delivered through mechanisms such as innovation, new product development, new product introduction, technology investment, training and education (5.3).

Enabling institutions assist the process of productivity by facilitating processes of innovation, upgrading of human factor endowments and the provision of an infrastructure to foster effective information transfers amongst member groups (5.4).

As an active 'network actor' or catalyst, enabling institutions offer the ability to promote the flow of information throughout the network reducing information asymmetries that are historically lost due to physical distance. Institutions for Collaboration (IFCs) further extend the role of enabling institutions by providing a 'network of networks' and a multi-dimensional participatory paradigm (5.5).

1.3 Primary Member Benefits and Activities

An industry survey was conducted early in 2004 to solicit feedback from industry stakeholders on various aspects relating to the activities of microelectronic design companies within the UK. The survey response rate was 15.3%, although the results are not conclusive they are indicative (6.4.5). The study indicates that the microelectronics design community within the UK would respond positively to the provision of activities and benefits discussed in the survey (6.4.5.4).

Industry looks to trade associations to provide forums to discuss current industry challenges and provide insight to industry trends and outlook.
Active participation is deemed crucial by the study and supported by secondary empirical studies (6.3.5, 6.4.5.4, 5.4.2).

Financial and marketing views were also clear (6.5):

- Finance – the results suggest that businesses are confident to approach venture capitalists and do not require assistance with forums or introductions. However, businesses would like to be made aware of government grants and tax incentives as they become available or when asked.

- Marketing – PR marketing such as global awareness of UK capabilities featured strongly in the results. Individual marketing communications such as speaking and publication opportunities featured negatively suggesting firms were confident to undertake their own marketing activities.

Observer and professionals would like to establish and maintain stronger links with academia for different purposes.

- Observers would like academia to become more commercially aware, developing business and product marketing skills (6.3.2.4).
- Businesses would like a channel between industry and academia to influence course content and keep universities up to date with current working practices (6.3.2.6.2).

1.4 Conclusions

In a fiercely competitive industry of continuous and sometimes rapid change, the importance of information flows and communication cannot be over stated. Efficient and effective forms of communication are needed to ensure firms benefit from timely information that will provide a competitive edge over foreign rivals. The propagation of best practice, tacit, explicit and market information assists productivity, efficiency and innovation processes (7.0).

This study indicates that the UK semiconductor industry would benefit from an extension of activities from existing organisations or a specialist trade organisation offering support in terms of collaterals and agency activities as described in section 6., and section 7. In this manner, the NMI may become an enabling institution.

Creating the database of 100 companies proved to be a challenge in its own right and therefore the design community is small enough to be approached individually in an on-going basis. Due to the specialist nature and size of the UK's microelectronic design sector, it is strongly recommended that the NMI adopt a direct approach to marketing with an emphasis on building relationships.

The value of partnering with other organisations to form a 'network of networks' is a powerful concept however care must be taken to architect a network which is purposeful, effective and avoids duplication of effort. This study recommends that purposeful partnering be further explored to extend member benefits and connect into the wider institutional network both at a national and international level (6.6).

Enabling institutions and IFCs play an active role in providing the infrastructure mechanism and means to contribute to a national comparative advantage in support of a move to a new strategy for UK competitiveness (5.5).

3.0 Semiconductor Industry: Context and Analysis

A brief tour of the global industry history, trends and business models is included here to provide the wider context for the study. Due to the limitations of space, only the major themes are included.

3.1 Trends

There are a number of trends associated with semiconductors and the industry ever since the nascent days of the transistor. Economic forces, technological advances and the desire to make devices smaller, faster and cheaper provide the drivers fuelling industry evolution. With the ability to make smaller and cheaper devices comes the opportunity to provide greater functionality - with more functionality comes greater complexity.

3.1.1 Technology

Associated with the trend to make smaller chips is Moore's Law – an often misquoted and misinterpreted trend. Writing for *Electronics* magazine in 1965, Gordon Moore noted that for the last three years, the number of components on an integrated chip had doubled yearly. Moore announced that this trend would continue for another ten years, a prediction that turned out to be true - far more accurate than Moore had ever thought it would be. The complexity of a chip continued to double yearly for long after 1975 and the rate of doubling only slowed to 18-24 months much later.

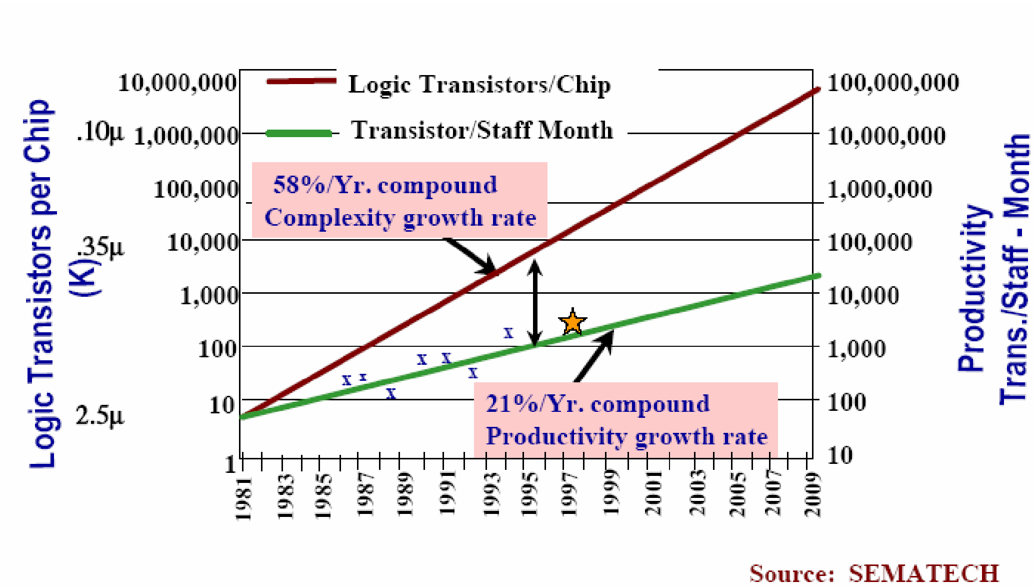
As transistor's and the interconnections between them get smaller, the speed of operation increases. IC's (chips) can therefore work faster and provide performance increases, whilst simultaneously reducing the amount of power taken on a 'per transistor' basis.

The following table illustrates the reduction in mimimum transistor features (microns) against speed and transistor volume increases between the different processors that Intel has introduced over the years. For comparison, a human hair is 100 microns thick.

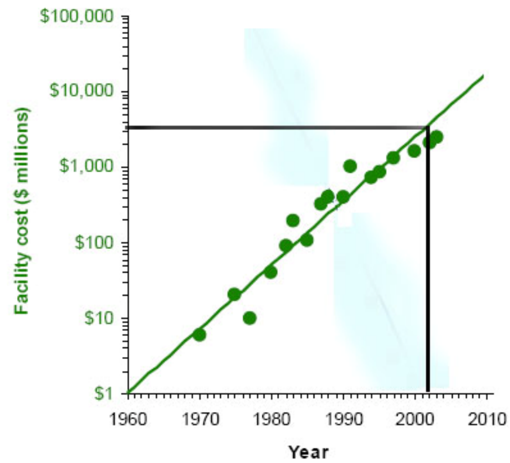
Name	Date	Transistors	Microns	Clock speed	Performance Measure (MIPS)
8080	1974	6,000	6	2 MHz	0.64
8088	1979	29,000	3	5 MHz	0.33
80286	1982	134,000	1.5	6 MHz	1
80386	1985	275,000	1.5	16 MHz	5
80486	1989	1,200,000	1	25 MHz	20
Pentium	1993	3,100,000	0.8	60 MHz	100
Pentium II	1997	7,500,000	0.35	233 MHz	~300
Pentium III	1999	9,500,000	0.25	450 MHz	~510
Pentium 4	2000	42,000,000	0.18	1.5 GHz	~1,700

On November 3rd 2003, Intel introduced the Pentium 4, 3.2Ghz, using 178 million transistors on a 0.13-micron process. (source: Intel)

Increased transistor density poses a problem for chip designers and their productivity. The gap that exists between the amount of transistors that can be manufactured versus the amount that can be utilised effectively is known in the industry as the 'Productivity Gap' (see Semtech chart below). Technical challenges that exist today are largely associated with the ability to rapidly design ever-complicated chips that work first time. This has lead to improvements in design methodologies (e.g. System-on-Chip and platform-based design), Electronic Design Automation (EDA) and compute-intensive emulation and simulation tools.



The chart above illustrates manufacturing productivity growth rate of 58% per year and designer productivity improvements of only 21% per year. The difference between transistors available and transistors utilised is known as 'The Productivity Gap'.



Source: IC Knowledge

Rock's law[1] predicts that silicon plant costs double every 4 years. Manufacturing improvements have seen an escalation in semiconductor processing equipment costs and hence the dramatic rise in foundry plant costs from under $10m in 1970 to over $2 billion today – See chart above. Despite these cost increases, transistor density gains and improvements in processing yields have contributed to a decline of 35% per year in product costs[2].

3.1.2 Cyclical Business

> *'From its beginning in the 1950s, the semiconductor industry has been characterized by a four-year cycle, sporadically modified by unexpected economic factors'* – Semiconductor Industry Association (SIA).

The cyclical nature of the semiconductor industry has been a permanent trend right from the early days. The rule of thumb that has been typically used is a 4 year cycle, however the most recent downturn started at the beginning of 2000 and only made tangible signs of recovery in the second half of 2003 making it the longest and deepest recession in semiconductor history. Semiconductor demand is steady but market forces and company investments produce the cyclical effect. As the industry cycle reaches a point of over capacity, companies cease to invest in leading edge manufacturing capacity and prices rise with demand. As the demand for leading edge processes rise more capacity is added until, once again, capacity is in excess thus starting the cycle again.

The difficulty of forecasting the industry cycle comes with the *'sporadically modified and unexpected economic factors'*. In 1999 the industry enjoyed boom times - these were largely fuelled by a rush of spending in telecommunications equipment for the internet and PC equipment to avoid the looming millennium bug problems associated with older equipment.

Many felt the *'over exuberance'* of company executives and investments encouraged by the boom would cause the industry to overheat. Sure enough, as one foundry executive told the author in 2000 *'everything looked fine until one day in December* [1999] *when orders fell off a cliff'*. Several factors combined to extend the depth and length of the industry downturn. *'Double order booking'* meant that demand was significantly over forecasted resulting in supply chain over capacity. An excess of nearly-new telecommunications infrastructure equipment (switches/servers/routers etc.), became available due to the burst of 'the Internet bubble' (hype associated with the fortunes associated with Internet enabled business models). These two factors conspired to exacerbate the supply chain problems and extending the delay in demand while new and nearly new stocks depleted.

3.1.3 The Only Constant is Change

The pace of technology helps to open up new markets that were unavailable before and older markets mature and wither. This trend requires that the long-term successful companies must reinvent themselves and their markets on a regular basis.

3.1.3.1 Case Study: Intel

In 1968 Intel (short for Integrated Electronics) was formed by two ex-Fairchild Semiconductor executives. In 1970, Intel developed the first dynamic memory (DRAM) chip, the *'1103'* - it was the first chip cheap enough to be used for memory in mainframe computers, and it became a very important product for them. Following the DRAM business, the company began to look for *'some other large-volume, complex chips'* to build. The electronic calculator market was just opening up but Intel *'were late to the party'*. Ted Hoff, a systems engineer at Intel, realised that Intel could provide the circuitry needed on a general-purpose architecture – the original idea for the microprocessor. Intel sold the microprocessor design to their customer, Busicom in its entirety. Having realised that they had sold the intellectual property for the microprocessor cheaply, Intel took advantage of Busicom's financial misfortune and returned the original development costs *('which I think was $60,000'*) in return for commercial rights on all non-calculator applications[3].

In 1985, *'the* [DRAM] *memory industry was losing money by the bucketful'* and Intel decided to withdraw from the market and focus on microprocessors and *'that decision turned* [Intel] *into a powerhouse in microprocessors'*. Intel rode the fortunes of the personal computer market for many years with a strategy of rapid product development and improved technological performance. However, recently the outlook for the PC market appears less attractive than it has done in the past causing Intel to reinvent itself for the second time since 1985. *'Intel unveiled a new family of chips for the networking and communications gear that zips data traffic through the arteries of the Internet. That's a $7 billion opportunity--and it's growing 30% faster than PC processors'*[4].

3.1.4 Start-ups and Progenitor as Competitor

The proliferations of new businesses from the ranks of trading companies is a regular occurrence as entrepreneurs become dissatisfied with their employers or identify an opportunity with attractive personal financial rewards – e.g. See Appendix A

3.2 Semiconductor Company Evolution

Two of the most significant forces that have shaped the structure of the industry have been product complexity, itself enabled by the observations of Moore's Law, and manufacturing costs. The evolution of the industry into its component parts has been a continuous process (See Semiconductor Company Ecology Chart below) but can be described in three distinct stages of outsourcing trends.

Stage 1: Fully integrated Design and Manufacture

Companies involved in the early stages of the industry provided all functions as a necessity to produce semiconductor products. Primary functions in the value chain include:

- Semiconductor materials.
- Semiconductor processing and handling equipment.
- IC design.
- Design tools.
- Photolithographic mask making.
- Silicon wafer foundry processing and
- IC Device assembly and test.

Engaging in design, manufacturing and marketing activities lead to further innovations to gain efficiencies in the product creation process. The beat of technological advancement continued, companies developed greater understanding and mastery over all processes. Opportunities to outsource non-critical items or specialist equipment opened up and created additional supply companies to the industry. Industry evolution invited the division of labour and the creation of specialist staff functions in areas such as R&D, design and manufacturing.

Stage 2: Design and Manufacture Separate – Fabless Model Is Born.

Manufacturing foundry costs continued to rise during the 1980's. In 1987 TSMC, the worlds first 'pure-play' foundry services company was formed. This allowed new semiconductor companies such as Xilinx to outsource their production requirements (see side box). Following on from the success of TSMC, the pure-play foundry model has proliferated around the world giving

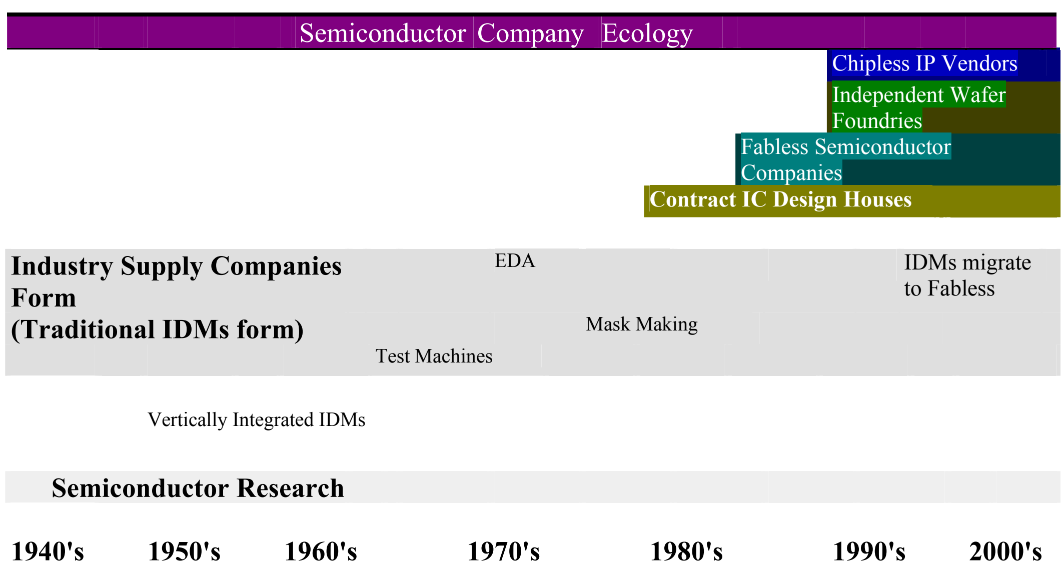
> *Bernie Vonderschmitt, an engineer and an MBA graduate, came up with a powerful business model for the young [Xilinx]. When he was General Manager of the Solid State Division of RCA, he became convinced, working at the time with three in-house foundries making semiconductors, that semiconductor factories (or fabs) were expensive and burdensome. "If I ever start a semiconductor company, it will be fabless," he vowed. "We'll find partners who can do our manufacturing for us."*
> http://www.xilinx.com/company/xilinxstory/history.htm

greater capacity and allowing more companies to adopt a 'fabless' (fabrication-less) business model. In 2002, the Fabless Semiconductor Association (FSA) estimated that in North America alone, there were over 500 fabless companies, with over 700 world-wide.

Stage 3: Design and Intellectual Property (IP) Separate: Chipless Model Is Born, Manufacturing Integrates.

The growing complexities of products, the shortening of product life cycles and the problems associated with proving designs (verification) prompted advances in design methodology and the need for design re-use. That is, circuit design elements that are known to work can be re-used in new designs to reduce the risk of design failure. Larger configurations of circuits for re-use continued until whole functions, such as a microprocessor core, were used to make (in theory at least) significant reductions in the product design cycle. These functional blocks provided opportunities for a new model of business – the IP model. Firms that use the IP model are also termed 'chipless' as they do not manufacture chips beyond the proof of performance and functionality stage.

As the pure-play model matures, it extends 'turn-key' manufacturing to its customers thereby increasing its services and product offerings.



Source: Future Horizons/JWM

The situation that exists today displays a diverse set of firms, in a variety of configurations and business models:

3.3 The Strategic Groups

The prevalent business models provide the basis for analysis in the survey as described below.

3.3.1 Integrated Device Manufacturer (IDM)

IDMs of today are termed 'traditional IDMs' and differ slightly from the early fully vertically integrated companies. Although they run and operate their own foundry plant, they rely on third party suppliers for specialist equipment and Electronic Design Automation (EDA) tools etc. These companies create their own products and believe that manufacturing is a core competence that allows them to compete more effectively. Archetypes of this model include Intel Corporation, IBM and Texas Instruments. The downside to this model is that it is capital intensive and difficult to maintain technological leadership with significant cost increases between process generations. It is projected that the number of IDM's will fall significantly in the future due to the significant costs associated with building a state-of-the-art foundry. In July 2002, the FSA estimated that income from the (at that time) state-of-the-art foundry had to generate at least $7billion to make it viable (see box insert). As a result, IDM's may mitigate costs by providing foundry services too – e.g. IBM is a top 5 foundry provider as well as an IDM.

> *'Second-and third-tier IDMs will be forced to adopt a pure fabless strategy or a fablite strategy to remain viable. Over the next 18 to 24 months, up to 20 IDMs will make this transition.'*
> Joe Osha, Merrill Lynch (March 2002)

3.3.2 Fablite

The fablite model is an evolutionary step between the IDM model and becoming a fabless semiconductor company. In this stage, the company owns and maintains its own foundry plant and wafer making capability but have a policy of outsourcing part of its manufacturing requirement to merchant pure-play foundries.

The advantage of this model is that it gives the fablite companies choices as to manufacturing: shared risk and ensuring better asset utilisation during industry down-cycles. Companies that operate this model must pay attention to their manufacturing planning to ensure they realise the benefits and savings of this approach. Archetypes of this model include Motorola and Infineon Technologies.

In practical terms, fablite companies are either grouped with IDM's or fabless dependent on the degree of outsourcing or foundry ownership. This definition is provided for completeness.

3.3.3 Fabless

A fabless company is one that designs and markets its own semiconductor devices yet has no foundry plant or wafer production capability. In practical terms, a company is regarded fabless if most (75% or more) of its manufacturing requirement is out-sourced to a third-party foundry. The advantage of this model is that companies can focus on value added functions of design and marketing of their products without incurring the expense of running state-of-the-art manufacturing. Morris Chang, the chairman of TSMC notes the significance of this focus when he said *'Fabless companies will come out of a downturn particularly strong because every R&D dollar is going to next-generation product design.'* [5]

The downside of this model comes when third-party foundries become fully utilised giving the fabless company a problem of competing for foundry services. In response to this uncertainty, a number of *follower* foundries offer leading foundry *mimic* processes[6]. Archetypes of this model include Nvidia, Xilinx and Broadcom.

3.3.4 Intellectual Property Provider

Focussing purely on design related activities yields the Intellectual Property (IP) or Chipless model. With advances in engineering methods, techniques and languages, it is now possible to offer a product that can be delivered ready for further integration into a customer's IC design.

The subject of IP is sufficiently complex that it deserves more space than is allocated here – for our purposes, we shall adopt a simplistic view of IP. There are several varieties of IP products but the most prevalent are the 'star' IP product and the functional IP products. Star IP products allow customers to benefit from either a performance characteristic of the IP or application knowledge. For example, Rambus Inc., provides star IP cores which allow high performance memory devices to be used, ARM offer embedded microprocessor expertise (components, software tools, design etc.) to its customers. Functional or portfolio IP companies may offer a selection of general purpose cores which are proven and save the customer time and effort in designing their own versions. Examples include communication standards such as USB or firewire.

Advantages of this model include lower engineering and operations costs but practically it is difficult to implement especially for start-up companies who have trouble winning customer confidence and generating short-term revenues.

3.3.5 Service: Design & Manufacturing

Companies that do not design and market their own products may offer product design and/or manufacturing services to those companies who do. These firms sell experience and design or process expertise and may even have their own IP. Typically firms selling product design services will not have the same potential for commercial exploitation of IP as for those companies selling IP only.

The advantage of this model is that there is little risk associated with product markets. The escalating costs associated with design tools for leading edge foundry processes is a challenge for firms that operate this *'cost-plus'* model and do not add value in other ways. When design capability is scarce, market forces drive prices up and these companies make very good profits. When there is over-capacity, competition puts downward pressure on prices, which could be fatal for smaller service firms. Customers of these types of companies may view their use as 'tactical' as opposed to 'strategic' outsourcing thus they may not represent long term business opportunities.

3.4 Business Model Analysis

Further analysis of the business models, revenues and geography of firms provides further insight into the investment and risk that is associated with each model.

3.4.1 IDM

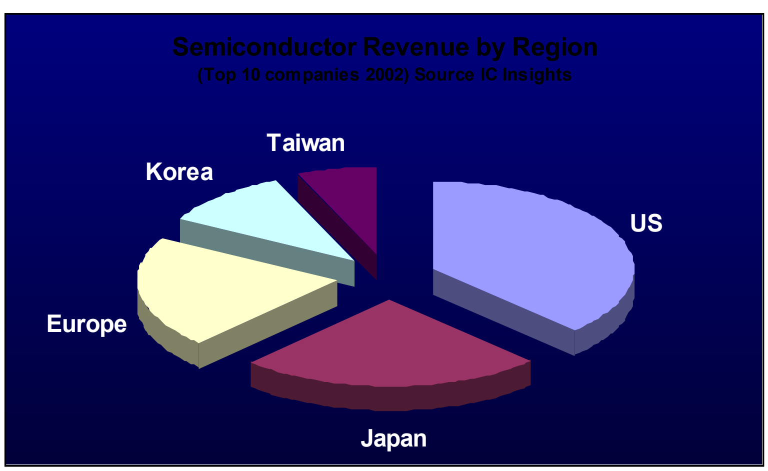
As can be seen from the table below (see: forecasted 2003 Top 10 Semiconductor Ranking), Intel is by far the largest revenue generating semiconductor company accounting for approximately 15% of industry revenue, 3 times larger than that of its nearest rival.

Forecasted 2003 Top 10 Semiconductor Ranking ($M)					
2003 Fcst Rank	**2002 Rank**	**Company**	**Headquarters**	**2003 Sales (Fcst, $M)**	**2002 Sales ($M)**
1	1	Intel	US	27,030	24,084
2	2	Samsung	South Korea	10,125	8,730
3	3	Renesas*	Japan	8,995	7,925
4	4	Texas Instruments	US	8,210	6,700
5	5	Toshiba	Japan	7,975	6,481
6	6	STMicroelectronics	Europe	7,145	6,354
7	8	Infineon	Europe	6,885	5,375
8	7	NEC	Japan	6,250	5,700
9	10	TSMC**	Taiwan	5,900	4,655
10	11	Philips	Europe	5,600	4,361
	Total			**94,115**	**80,365**

Source: IC Insights

*Officially formed on April 1 2003
Combined sales of Hitachi and Mitsubishi
** Pure-play Foundry

In regard of revenue ranking by geography, the US has 37.4%, Japan 24.7%, Europe 20.9%, Korea 10.7%, Taiwan 6.3% - note that Taiwan's entry is a merchant foundry and not a product company.



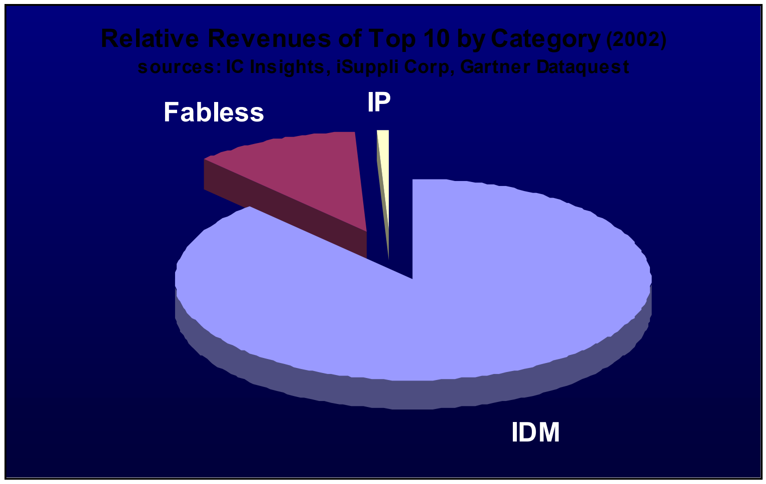
3.4.2 Fabless

In comparison to the IDM model, the top 10 fabless companies have combined revenues of $12.7bn – only 13.5% of the top 10 IDMs. The largest fabless company, Qualcomm ($2510m) is forecasted to have less than half the revenues of the 10th largest IDM (Philips, $5600m) illustrating the relative revenues of each business model. Looking at the location of the fabless firms is illuminating: 23 of the top 30 reside in North America (USA & Canada) and the remaining 6 in Taiwan – there are no European, Japanese or Korean entries.

Leading Fabless IC Suppliers ($M)					
2003 Fcst Rank	**2002 Rank**	**Company**	**Headquarters**	**2003 Sales (Fcst, $M)**	**2002 Sales ($M)**
1	1	Qualcomm	US	2,510	1,942
2	2	Nvidia	US	1,835	1,915
3	4	Broadcom	US	1,595	1,083
4	3	Xilinx	US	1,265	1,125
5	5	MediaTek	Taiwan	1,170	854
6	8	ATI	Canada	1,135	645
7	10	SanDisk	US	930	493
8	7	Altera	US	830	712
9	11	Marvell	US	780	482
10	9	Conexant*	US	650	627
11	6	VIA	Taiwan	620	729
12	12	QLogic	US	520	415
13	18	GlobespanVirata	US	360	229
14	16	Sunplus	Taiwan	320	250
15	23	Novatek	Taiwan	311	193
16	24	Silicon Laboratories	US	310	182
17	15	Realtek	Taiwan	300	265
18	17	SST	US	250	244
19	21	PMC-Sierra	Canada	245	213
20	20	ICS	US	237	228
21	19	Lattice	US	218	229
22	29	Zoran	US	213	141
23	22	Genesis Microchip	Canada	211	196
24	28	SMSC	US	202	145
25		Zarlink**	Canada	201	
26	25	ALi	Taiwan	200	176
27	13	Cirrus Logic	US	198	304
28	14	ESS	US	180	273
29	32	DSP Group	US	170	125
30	26	Semtech	US	160	170
		Others		2,514	2,210
		Total		**20,640**	**16,795**

Source: IC Insights

*Merger planned between companies 1Q, 2004
** Became fabless mid-02



Taking a wider view at the top 25 semiconductor companies (see table below: Preliminary 2003 Semiconductor Market Share)[7], it is easier to compare the relative standing of the top fabless company against the IDMs and the fablite companies.

Preliminary 2003 Semiconductor Market Share Top 25 Suppliers of Semiconductors Worldwide						
2003 Rank	**2002 Rank**	**Company**	**2002 Sales ($M)**	**2003 Sales ($M)**	**% of Total**	**% Cumulative**
1	1	Intel	23,702	26,723	15.0%	15.0%
2	2	Samsung	8,751	9,514	5.3%	20.3%
3		Renesas		7,946	4.5%	24.8%
4	3	Toshiba	6,422	7,684	4.3%	29.1%
5	4	Texas Instruments	6,380	7,515	4.2%	33.3%
6	6	Infineon	5,375	7,235	4.1%	37.4%
7	5	STMicroelectronics	6,354	7,035	3.9%	41.3%
8	7	NEC	5,321	5,696	3.2%	44.5%
9	9	Philips	4,361	5,602	3.1%	47.6%
10	8	Motorola	4,807	4,806	2.7%	50.3%
11	12	Matsushita	3,280	3,783	2.1%	52.4%
12	16	Sony	2,791	3,368	1.9%	54.3%
13	14	Micron	2,895	3,361	1.9%	56.2%
14	20	Sharp	2,267	3,080	1.7%	57.9%
15	18	Hynix	2,392	2,978	1.7%	59.6%
16	13	Fujitsu	3,126	2,712	1.5%	61.1%
17	15	IBM	2,808	2,537	1.4%	62.5%
18	22	Sanyo	2,121	2,500	1.4%	63.9%
19	23	**Qualcomm**	1,941	2,379	1.3%	65.2%
20	19	Rohm	2,390	2,353	1.3%	66.5%
21	25	Analog Devices	1,770	2,172	1.2%	67.7%
22	17	AMD	2,661	2,044	1.1%	68.8%
23	21	Agere Systems	2,197	1,913	1.1%	69.9%
24		Spansion		1,748	1.0%	70.9%
25	24	**nVidia**	1,812	1,729	1.0%	71.9%
		Others	50,643	49,975	28.1%	100.0%
		Total	**156,567**	**178,389**	**100.0%**	

Source: iSuppli Corporation Dec 2003

Qualcomm ranks 19th with Nvidia (2nd largest fabless) just making the 25th ranking. Also note the multiplier (11 X) in revenue terms between Intel and Qualcomm. It can be seen from these figures that IDMs are able to (and need to) exploit more economic value by maintaining their own manufacturing plant.

3.4.3 Intellectual Property Providers

ARM (UK based) is the world's largest vendor of semiconductor intellectual property (IP). In 2002 ARM, with revenues of $185m, had almost double the revenues of the second largest IP provider, Rambus ($97.4m)[8]. ARM ranks between Cirrus Logic (27th) and ESS (28th) against the top 30 fabless companies with Rambus (ranked 2nd largest IP provider) having no proximity.

2002 market share estimates of the semiconductor IP licence industry

Company	2002 Revenue ($m)	2002 Market share (%)	2001 Revenue ($m)	2001 Market share (%)	Type
ARM	184.9	19.8	168.0	18.8	Processor
Rambus	97.4	10.4	107.3	12.0	Memory I/F
Synopsys	73.2	7.8	45.0	5.0	Block library
TTPCom	58.0	6.2	39.5	4.4	Platform
Parthus Ceva	51.2	5.5	40.9	4.6	Varied
Virage Logic	47.5	5.1	34.8	3.9	Memory/Logic
Artisan	43.7	4.7	27.8	3.1	Varied
MIPS Technologies	43.1	4.6	70.2	7.9	Processor
Mentor Graphics	25.7	2.8	30.4	3.4	Functional
Monolithic System Technology	24.9	2.7	9.5	1.1	Memory

Source: Gartner Dataquest

3.4.4 Services: Design and Manufacturing

While there are numerous design services companies, there appears to be little market data on any sizeable business. In 2000, Tality (a division of Cadence Systems) was the leader in the highly fragmented market for independent design services. Its sales were almost $200 million, with 55% of that coming from chip design - the rest of the revenues were attributable to design projects for systems and subsystems. Cadence moved to spin Tality off in a separate IPO, however, in its 2002 annual report Cadence reported:

> *'In April 2001, Cadence announced the withdrawal of the Tality IPO registration statement' and further noted that 'Cadence no longer has a separate design services group named Tality'*

Zaiq Technologies a competitor of Tality at the time, had revenues of $34m in 2001[9].

Despite the lack of market data, perhaps the greater interest here is the trend to outsource design related activities to lower cost regions of the world. There are a growing number of companies that are either opening up subsidiaries in lower cost regions such as India, or outsourcing to companies in these regions. The Electronic Design And India website[10] lists in excess of 100 companies which have facilities in India including ATI, Infineon, Texas Instruments, STM, Philips, Broadcom, Cisco Systems and Cirrus Logic. A report commissioned by the SWRDA[11] notes *'in the New Delhi area, ST Microelectronics already operates a successful in-house IC design operation, with more than 800 designers'* – the same report identifies the UK's total number of engineers at approximately 3300.

In a recent article in The Gulf News*, Azim Premji, chairman of Indian technology company Wipro said *"The number of graduates with engineering degrees in India this year (2003) is 280,000, and the supply is expected to go up 10 per cent annually. Add another 300,000 engineering diploma holders, and this is a huge base. The average starting salary for engineers in India is $6,000 a year… the starting salary in Europe is $45,000 to $50,000 a year"*.

* Source: http://www.gulf-news.com/Articles/news.asp?ArticleID=98906

3.5 Applying Porters 5 Forces to the Global Semiconductor Industry

The variety of business models, hybrid model configurations and the broad spread of market areas (see top 10 IC product types in 2003) make generalisations difficult or of limited use when considering the effects at the micro-economic level. However, the model does help to understand the forces that drive or influence companies to migrate their positions over the long term and the industry cycle.

Top 10 IC product types in 2003		
Product	Market ($bn)	Increase (%)
Flash memory	11.16	44
Digital Signal Processor (DSP)	6.10	26
Special purpose communications logic	5.04	43
Display drivers	4.51	27
Voltage regulators and references	4.32	21
System support special purpose logic	3.96	24
32-bit Micro Controller Units (MCUs)	2.73	29
Programmable Logic Devices (PLDs)	2.58	33
Data conversion	2.10	38
Industrial applications specialist analogue	1.34	26
		Source: IC Insights

The high-growth IC areas of 2003 were those associated with mobile phone applications: flash memory, communications logic, data conversion, display drivers and DSPs. IC Insights predicts the top ten products are continued growth until 2007 with a collective compound annual growth rate (CAGR) of 32 per cent.

3.5.1. Threat of New Entrants

3.5.1.1 IDMs

There are significant barriers to entry for this model due to the high costs of building state-of-the-art foundry capability. Mark Edelstone (Morgan Stanley) argues that *'Digital IC Companies With Annual Revenues Below $4-$5 Billion Can't Afford [state-of-the-art] 300mm Fabs'*, noting that only 8 companies have those levels of income[12]. Therefore there is a low probability of new IDMs. New entrants will likely be alliances or joint-ventures of companies that combine finance and knowledge resources such as that of Renesas Technology (April 2003, Hitachi and Mitsubishi).

Assuming that the running costs and operating efficiency of merchant foundries is the same as an IDM running its own foundries, it is likely that IDMs will capture more market share of commodity products such as memories and low performance microprocessors. This is because unit costs will be higher for fabless companies as they will pay the premium required by the foundries to remain profitable. Fabless companies will therefore focus on design value added products.

3.5.1.2 Fabless

The fabless model is growing faster than other sectors of the industry in the world. Barriers to entry are low with relatively low costs. This model is also attracting the IDMs - migration is due to the low barriers of exit/entry for IDMs. Fabless companies are attracted to markets that can sustain a premium on design added-value and where markets represent high profit and revenue opportunities they will face competition from IDMs who will have a manufacturing cost advantage.

3.5.1.3 IP

There appear to be low barriers to entry for this model however the difficulty in attracting early customers, finding the right business model, the high support costs and the many failures will act as a deterrent. IDMs, fabless, design services and other supply companies (e.g. EDA providers) may use this model to complement their primary business model, offering customers an alternative form of product delivery or extension of product portfolio.

3.5.1.4 Design and Manufacturing Services

In the most recent downturn, design service companies have been finding conditions difficult as their customers fully utilise their own in-house design capability. Therefore, in-house capability represents a new entrant threat when the industry enters a cyclical downturn. Those companies that offer unique expertise or IP will fare better than those offering generic services whom may find themselves fighting for survival.

3.5.2. Power of Suppliers

3.5.2.1 IDMs

Suppliers to the large semiconductor companies tend to have little power. This is because they usually diffuse the risk of supply across many suppliers – Toshiba, for example, maintain over 400 suppliers. This is not universally true however and there are numerous examples of small numbers of highly specialised suppliers that enjoy power associated with scarcity of resource.

3.5.2.2 Fabless

The main drawback of the fabless model may allow merchant foundries to exert power over them especially during cyclical upturns when demand makes capacity scarce. As described earlier, this situation may be accommodated by second sourcing foundry with 3rd party compatible processes.

3.5.2.3 IP

There are no significant supplier problems for chipless companies.

3.5.2.4 Design and Manufacturing Services

Those companies which offer manufacturing services via a third party foundry will suffer the same problems as fabless companies during cyclical upturns. There are no major supplier issues for design companies.

It is worth mentioning EDA as a common influence on all categories of design-related activities. Innovation and advances in design tools are a key requirement to support the latest process developments. Productivity gains derive from evolutionary and revolutionary methodologies, tools and design languages. Although there are a number of small EDA companies with new companies being formed all the time, the industry is heavily biased towards three main providers: Cadence, Synopsis and Mentor Graphics. This low concentration of suppliers provides more of a problem for small design companies (fabless, IP and services) as entry level ‘flows’ have a high price and quantity discounts are not appropriate. Therefore, EDA firms typically exert greater power over smaller companies than they do for larger companies.

3.5.3. Power of Buyers

3.5.3.1 IDMs

This is highly dependent on market sector and the number of competitors. Intel has enjoyed the number one position of a small number of suppliers in the PC and server microprocessor markets retaining strong profit margins. Memory markets fluctuate on a regular basis due to the volumes manufactured and the number of competing firms. When there is over capacity, several of the large memory suppliers may use their foundries for other products until supply levels favour memory producers once again.

3.5.3.2 Fabless

This is also dependent on market sector. Once a company has established itself as a significant supplier to a market it is difficult for others to displace the incumbent due to switching costs. However, if there are regular opportunities for purchasers to review products with improved performance features – such as OEMs and PC graphics, the buyers will have greater power and possess less loyalty.

3.5.3.2 IP

Unless the IP provider has a unique product (such as Rambus), purchasers of IP tend to have a great deal of power. Often IP cores are available from a number of different suppliers allowing competition. Factors that influence IP acquisition include the number of successful design implementations, licensing terms, trading history and portability – making it difficult for new IP companies to gain market entry.

3.5.3.3 Design and Manufacturing Services

This depends on the phase of the economic cycle and follows the law of supply and demand. As noted earlier, during cycle downturns buyers will have a great deal of choice and power, during the up-cycle supplier firms will posses more power to take on more attractive and lucrative work.

It is possible to generalise on the remaining forces:

3.5.4 Availability of Substitutes

The semiconductor industry routinely protects market position by using intellectual property protection mechanisms such as patents and trade secrets. A firm that gains strong profits will naturally become the target of competition. If such a company has not protected its position it may find it difficult to recoup product R&D and market development costs when the new competitor (substitute) has fewer associated costs to recover.

3.5.5 Competitive Rivalry

The industry is marked by intense rivalry between companies and there is constant pressure to develop faster, cheaper and better products. Innovation provides a continuous and rapid flow of changes and additions to products, business models and industry structure. The result is an industry that continually produces cutting-edge technology while navigating volatile business conditions.

3.6 The Context for UK Semiconductor Company Competitiveness

Porter & Ketels study discusses the generic macro-economic status of the UK but does not specifically mention the semiconductor industry. The context in which businesses operate is significant to the economic performance of the country because *'wealth is actually created at the microeconomic level – in the ability of firms to create valuable goods and services using efficient methods'*[13].

Porters national diamond[14] has been adopted to provide the framework of analysis due to its wide awareness.

3.6.1 Factor Conditions

3.6.1.1 Applications Skills

The UK has strong product application skills in signal conversion, media communications, telecommunications, microprocessor design, computer graphics and video processing.

3.6.1.2 Technical Skills

Many of the careers associated with the industry require vocational qualification (HNC/HND) or a graduate level degree of education in a technical discipline.

Typically, engineers will hold a first degree (or equivalent) in a subject such as electronic engineering, computer science or physics. To maintain the industry, it is important to ensure the supply of engineering talent and this has become a topic of concern in recent years as numbers are decreasing. Between 1995 and 2000, the number of entrants to physics and engineering degrees fell by 7 per cent. The *'strengthening demand'* for graduates and the *'declining numbers of mathematics, engineering and physical science graduates is starting to result in skills shortages*[15]*'*.

> *Economic research demonstrates that the employment of well-qualified engineers and scientists pays off both in terms of national competitiveness and company profitability.*
>
> *Studies of international competitiveness and skill levels demonstrate that the British engineering industry may suffer from a "latent" or "concealed" skills shortage, over and above any skill gaps currently perceived by employers.*[16]

It is also typical to find relatively high numbers of staff with advanced degrees such as Master of Science (Msc) or doctorate (EngD/phD) in semiconductor companies. The level of competition and changing nature of the industry necessitates that practising engineers remain current, acknowledging the need for Continuos Professional Development (CPD)[17].

The 'Chips for Everything' report[18] (C4E) identifies a number of concerns regarding the supply of labour to the semiconductor industry and breaks these down into stages of *'the skills supply chain'*.

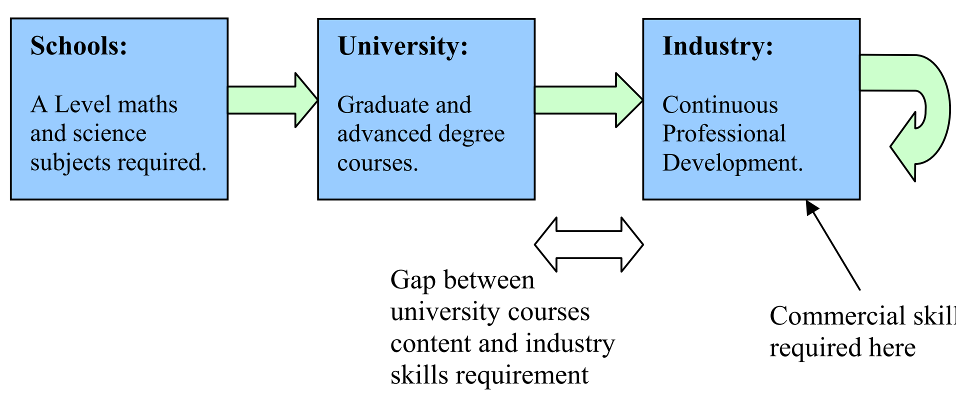
3.6.1.3 Schools

The declining numbers of school pupils[19] taking A-level mathematics and science subjects is a concern as there is a reliance on these subjects as entry requirements for relevant university courses. The industry's lack of influence to correct this situation is also highlighted[20].

3.6.1.4 University

The transition from university to industry can be a difficult transition for students and employers. Universities courses have been criticised for not providing the balance of software and hardware skills that the UK industry could better utilise. The C4E report notes that *'in computing subjects there is still a shortage of… skills that companies in the microelectronics design industry are seeking'*. Our study supported this finding with comments from one recruiting company[21] noting difficulties in finding computer science graduates with relevant knowledge necessary for implementing design.

The Education and Training Skills Pipeline



3.6.1.5 Management Skills

Management within the industry is typically supplied from the technical ranks as engineers progress their careers. Typically, individuals reach a stage when they must decide whether to take a managerial track or stay focussed on technical issues. Man-management, project management, people and commercial understanding are typical skills required for the management transition. These are portable and generic skills and courses are generally available to support new or inexperienced management personnel. The Porter & Ketels report was asked to pay *'special attention… to the role of management in UK competitiveness'* in the study. In conclusion, the report found that *'management practices… are not at the core of the UK competitiveness challenge'* and went on to say that *'there is always room for improvement'*.

This study has further separated the management function between senior management functions and middle management functions. Economic performance of the dominant SME companies is largely related to the performance of senior management. Due to the scale of the industry within the UK, there are few senior managers with pedigree's of success. Perhaps more importantly, there is even less entrepreneurial talent that has a history of success and this affects the supply of finance into the industry.

In addition, the C4E report identifies the problems of finding senior management *'that understand business plans, finance, cash flow and routes to market'* for start-up companies[22].

Therefore, the impact of management should not be dismissed quite so readily. Although good management has always been assumed to improve productivity, a recent study observed the effects of implementing modern management techniques within manufacturing companies. The study found that *'the correlation between a company's management practices and its financial performance was significant'*[23]. On a broader perspective, a more recent report funded by the European Commission noted *'There is strong statistical evidence that management development leads to superior organisational performance across companies of all sizes, sectors and national location'*[24]. The report notes that the UK is falling behind in developing its managers for the future compared to 6 other European countries.

3.6.1.6 Capital Resources

Despite the fact that sources of finance within the UK are strong with the availability of VC funds amongst the highest in Europe, there are some unique industry and location issues. The sum of money required to start a new venture within the semiconductor industry is sizeable. Set-up costs are typically high due to labour rates and infrastructure costs such as EDA tools and computer equipment. The length of time that it takes to bring a new product to market can be measured in years rather than months resulting in a sustained requirement for investment. '*Once a start-up company is established, it can spend money at an alarming rate'*[25]. Options for financing therefore typically need investment from different types of financial partners depending on the stage of funding required. Early stage funding is typically arranged through seed funds and will typically range up to £250,000. Venture Capitalists (VCs) tend to get involved in the later stages and enter at approximately £1million expecting significant returns within a 5-10 year period.

The number of equity firms that partake in semiconductor investments is relatively small compared to other general investments. This is because of it requires a degree of technology understanding and presents a greater risk – but it also presents a chance of higher return. Investments are in competition with other technology opportunities such as software, renewable energies, sensors, opto-electronics etc., which maybe easier to understand from a business perspective. This competition further thins out the number of investments made to semiconductors dramatically – typically only 2 or 3 investments are made per portfolio in a given year for technology companies.

With such high sums of money required, it is imperative that new starts are investor-ready. This means that firms will need to have developed a good business plan, identified a market and can demonstrate a good chance of market success before approaching sources of finance.
The general formula that VCs seek to satisfy when considering financial viability of a new organisation is: *Probability of Success = Management + Technology + Market*. This equation is not balanced – i.e. a company with a strong pedigree and demonstrable history of success in its management will greatly outweigh its investment attraction against a strong showing of technology. Thus capital flow is often strongly linked to senior management.

3.6.1.7 Scientific and Technological Infrastructure

UK Universities have a favourable international standing with many overseas students taking degree courses with UK universities at all levels (bachelors to doctorate) in engineering, science and management[26]. The top 10 universities for electronic engineering and computer science are shown below.

Top 10 UK Universities for Electronic Engineering

1	Southampton
2	Bristol
3	Imperial College
4	Edinburgh
5	Cambridge
6	Queens, Belfast
7	Sheffield
8	Surrey
9	York
10	Essex

Source: The Times On-line, December 2003, Good University Guide

Top 10 UK Universities for Computer Science

1	Cambridge
2	St Andrews
3	Southampton
4	Warwick
5	York
6	Bath
7	Imperial College
8=	Oxford
8=	Bristol
10	Edinburgh

Source: The Times On-line, December 2003, Good University Guide

Despite the favourable standing of UK universities they are considered to be deteriorating. *'A 2001 survey of Deans of Engineering showed that the greatest difficulty in recruitment was in the computer departments closely followed by electronics'*[27].

3.6.1.8 Research and Design (R&D)

Porter & Ketels draws attention to the low public sector investment in R&D[28] compared to many other advanced economies. Although recent government policy is to increase spending it will take time for the years of under investment to be overcome.

From April 1st 2000, the government introduced tax credits for SMEs participating in R&D activities. Although a welcomed gesture, there has been concern and confusion as to what qualifies for tax credits. Even the tax authorities have interpreted the rules differently with variation on the treatment of R&D tax credit between regions[29]. These concerns have been reported back to government and in December 2003, in a pre-budget statement the Chancellor Gordon Brown responded by stating *'I want Britain to be the best location for science and research and development and I can announce a widening of the successful R&D credit'*[30]. This suggests that the government is also looking to attract foreign firms to the UK to carry their R&D functions.

3.6.2 Related and Supporting Industries

The global nature of the semiconductor industry does not necessitate close proximity to the major suppliers of goods and services to the industry. There are three major suppliers to the domestic industry:

3.6.2.1 EDA

The EDA industry provides advanced design tools that allow engineers to be productive – without these tools a firm may suffer from a competitive disadvantage.
As noted above, there are three main suppliers of software tools necessary for the majority of the semiconductor design flow. These companies are US based companies but each has sales, marketing and support offices in the UK.

3.6.2.2 Foundry & Related

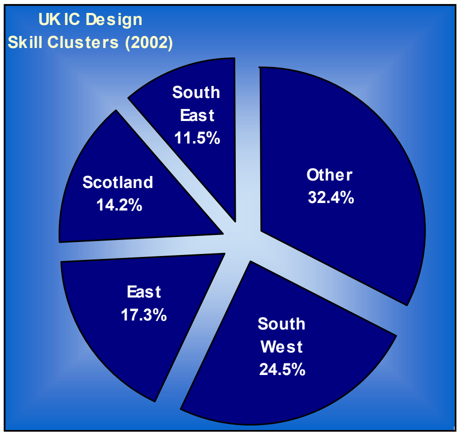
The UK has no state-of-the-art advanced foundry capability. There are approximately 20 mainstream manufacturing foundries in the UK, with about 30-40 other smaller clean-room facilities for development, characterisation, mask-making, tool development etc[31]. The prominent merchant foundries tend to be located in Asia in countries such as Taiwan and Mainland China.

3.6.2.3 Services

The UK has a strong mix of digital and analogue design expertise and represented just under 39% of the number of European IC contract design houses. This concentration of design services companies is due to the advanced stage of the industry cycle the UK has in relation to its European neighbours[32].

3.6.2.4 Cluster Development

There are three dominant areas for semiconductor activity within the UK. These have been dubbed: 'Silicon Fen' (Cambridge), 'Silicon Glen' (Scotland) and 'Silicon Gorge' (Bristol).

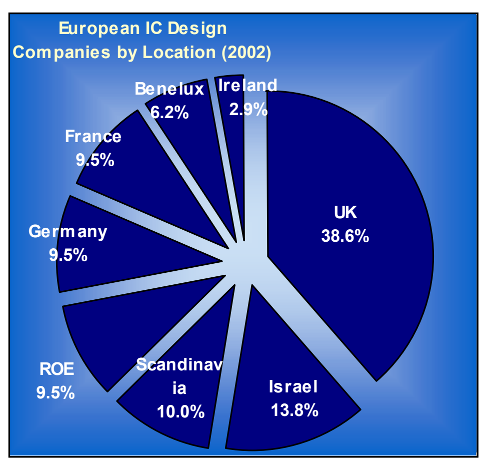


The most prominent of the regions is the South West of England (see chart: UK IC Design Skill Clusters) which boasts the highest concentration of design engineers in the UK. These clusters can be explained by proximity to the sites of latter day 'national champions', universities and government investment.

These clusters are superficial and do not conform to the definition Porter applies as they tend to be similar types of companies and occupy similar parts of the supply chain. In order for a cluster effect to work, related and supporting companies throughout the supply chain need to exist in proximity and either consume or provide input to other firms within the cluster.

3.6.3 Demand Conditions

Local demand conditions are weak within the UK. There are few sizeable UK based Original Equipment Makers (OEMs) that exist today[33]. The European Chipless & Fabless IC Design House Report by Future Horizons details the history of the break-up of the 'national champions' of the 1950's, 60's and 70's. The ensuing restructuring contributed to the proliferation of semiconductor design houses associated with the UK (see chart: European IC Design Companies by Location). Design houses typically sell their services to local semiconductor companies (IDMs and Fabless). Chipless and Fabless companies have a longer geographic reach and establish sales and marketing offices close to their markets.



UK firms have *'exerted more influence over global OEM production than its indigenous OEM industry size would merit'* as witnessed by the large number of GSM mobile phones designed in the UK but branded by foreign OEMs[34]. A particular example where local demand conditions have been overcome is ARM which, in 2002, accounted for over 75% of the worldwide market share for embedded RISC microprocessor cores.

3.6.4 Context for Firm Strategy and Rivalry

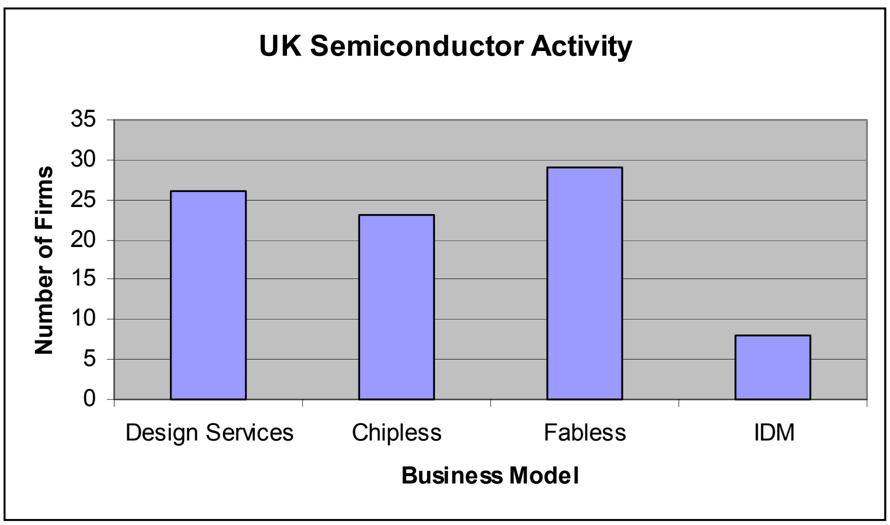
The UK has low barriers to foreign trade and overall low levels of tariffs. The UK also has the lowest level of product and market regulations within the OECD. Whilst the rate of new business formation is high, UK start-ups have a significantly lower likelihood of survival than its European and US peers[35].

Intellectual property rights protection is strong and provides a good environment for innovation and technology transfer.

3.6.4.1 Firm Strategy

In revenue and world terms, the fabless model is weak in both Europe and the UK with most fabless companies being located in North America and Taiwan.

Using the database created for this study, the number of firms operating the three prevalent models of fabless, chipless and design services in the UK is roughly equal.



Rivalries between UK semiconductor firms tend to occur in the area of staff recruitment rather than the application or product market place.

3.7 Summary SWOT Analysis

This material has been covered in the sections above. It is included merely to reinforce and summarise the analysis and is kept brief to avoid additional, and unnecessary duplication.

- Strengths – strong application skills in selected markets
- Weakness – lack of clusters, lagging productivity, skills gap/falling numbers of technical graduates, low concentration of successful industry executives
- Opportunities – application of technology to global markets in order to improve the UK business environment and economy
- Threats – lower cost regions of the world gaining competitive positions, not exploiting strengths effectively through slow or late responses

7.0 Conclusions

In a fiercely competitive industry of continuous and sometimes rapid change, the importance of information flows and communication cannot be over stated. Efficient and effective forms of communication are needed to ensure firms benefit from timely information that will provide a competitive edge over foreign rivals. The propagation of best practice, tacit, explicit and market information assists productivity, efficiency and innovation processes and ultimately the domestic comparative advantage.

An enabling institution may be effective by brokering information in all its forms yet it must be careful how information is handled. For example, too much information can be burdensome whilst meagre amounts add little value. The enabling institution will therefore need to be wary of what it transmits (information push) in formal communications and be careful not to limit flows amongst participating members during its activities and events. Additionally, the institution should consider how it handles demands for information (information pull) in order to fulfil member requests. In this way, the enabling institution collects, disseminates and creates opportunities for information exchanges between stakeholder groups and members.

The scale of the industry within the UK is small in global and relative terms. This suggests that a direct relationship between the institution and its members is possible allowing a richer dialog. The institution also needs to consider its public relations activity to ensure that domestic and international bodies (firms, institutions, government etc.) are aware of its work and position within the UK. This will further assist the overall objectives of information flows in support of its members.

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