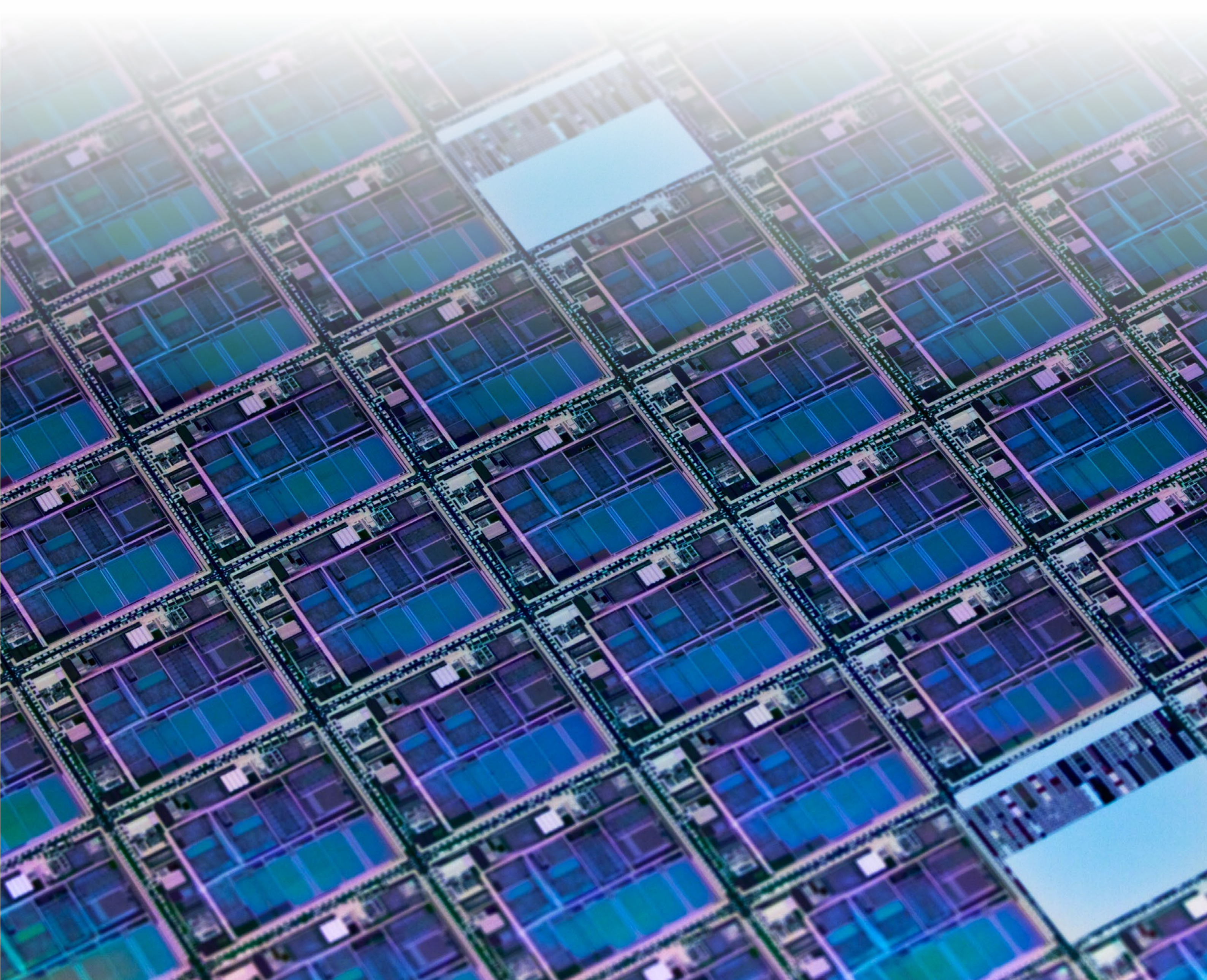
Semiconductors in the UK

Searching for a strategy

Geoffrey Owen

Policy Exchange



Semiconductors in the UK

Searching for a strategy

Geoffrey Owen

Policy Exchange is the UK's leading think tank. We are an independent, non-partisan educational charity whose mission is to develop and promote new policy ideas that will deliver better public services, a stronger society and a more dynamic economy.

Policy Exchange is committed to an evidence-based approach to policy development and retains copyright and full editorial control over all its written research. We work in partnership with academics and other experts and commission major studies involving thorough empirical research of alternative policy outcomes. We believe that the policy experience of other countries offers important lessons for government in the UK. We also believe that government has much to learn from business and the voluntary sector.

Registered charity no: 1096300.

Trustees
Alexander Downer, Pamela Dow, Andrew Feldman, David Harding, Patricia Hodgson, Greta Jones, Andrew Law, Charlotte Metcalf, David Ord, Roger Orf, Andrew Roberts, Robert Rosenkranz, William Salomon, Peter Wall, Simon Wolfson, Nigel Wright.

About the Author

Geoffrey Owen is Head of Industrial Policy at Policy Exchange. The larger part of his career has been spent at the Financial Times, where he was Deputy Editor from 1973 to 1980 and Editor from 1981 to 1990. He was knighted in 1989. Among his other achievements, he is a Visiting Professor of Practice at the LSE, and he is the author of three books – "The rise and fall of great companies: Courtaulds and the reshaping of the man-made fibres industry", "Industry in the USA" and "From Empire to Europe: the decline and revival of British industry since the second world war." He is the co-author, with Michael Hopkins, of "Science, the State, and the City: Britain's struggle to succeed in biotechnology"

© Policy Exchange 2022

Published by
Policy Exchange, 1 Old Queen Street, Westminster, London SW1H 9JA

www.policyexchange.org.uk

ISBN: 978-1-913459-94-9

Contents

1. Introduction

Should the UK have a strategy for semiconductors? This question has come to the fore in response to a series of events - some specific to the UK, others related to global developments – which have moved semiconductors (often referred to as chips or microchips) higher up the political agenda. These include: the current semiconductor shortage, which has severely affected some industries, especially the car makers; the semiconductor war between the US and China; and moves by Chinese companies to acquire European or American producers as a means of accessing semiconductor technology.

The shortage is expected to ease next year, but it has highlighted the extent to which the UK is dependent for supplies of a key industrial component on a global supply chain, some parts of which may be affected by political or economic shocks, or by natural disasters. This is one of the factors that prompted the Johnson government to ask the Department for Digital, Culture, Media and Sport (DCMS) to undertake a study of the industry.[1] The study will be published later this year.

The China factor has come into play for two reasons. Under both the Trump and Biden administrations the US has sought to limit China's access to high-technology products that might be used for military purposes. This means, among other things, restrictions on US exports of advanced semiconductors, of which China is a large importer. While these measures do not directly affect the UK, they are likely to cause some disruption in world semiconductor trade.

At the same time anxiety about China's ambitions has led the US and the European Union to restrict the ability of Chinese companies to buy local semiconductor firms. The UK has moved in the same direction. Through the National Security and Investment Act, which came into force at the start of 2022, the government now has stronger powers to block unwanted foreign takeovers. No countries are mentioned in the Act, but China is generally assumed to be the principal target. A test case of how the new powers will be used is the takeover by a Chinese-controlled group of Newport Wafer Fab, a semiconductor firm in South Wales, which is now being reviewed by the Department for Business, Energy and Industrial Strategy (BEIS).

The wider question of foreign acquisitions, not just from China, is also a matter of concern. There is no large British-owned semiconductor manufacturer comparable to Infineon in Germany, but the UK has strengths in other areas, notably in chip design and in compound semiconductors. The star of the design sector, and one of the UK's few world leaders in high

1. This department, previously the Department for Culture, Media and Sport, was given the "digital" title in 2017 to reflect its responsibility for growing the digital economy. In semiconductors it works closely with the Department for Business, Energy and Industrial Strategy (BEIS).

technology, is ARM, which has licensed its intellectual property to most of the world's mobile phone makers. In 2016 this company was bought by SoftBank, a Japanese financial group. Four years later, SoftBank changed its mind and proposed to sell ARM to one of the largest American design firms, Nvidia. In the face of opposition from regulators on competition grounds, Nvidia did not proceed with the deal, but the episode reinforced a widely held view that the government should be willing to intervene to maintain British control of important high-technology companies.

Beyond these British concerns, there is a general recognition that semiconductors will play an increasingly important role in coming years, not just as an essential component for other industries but also as a driver of progress in emerging technologies such as artificial intelligence; they also make an essential contribution to national security.

The UK government, like its counterparts in the US and the European Union, is looking for ways of strengthening the domestic semiconductor industry. Any new policies in this sector have to take into account recent changes in the structure of the world semiconductor industry, and where the UK fits into it.

2. The world semiconductor industry

Since the invention of the transistor in 1947 the semiconductor industry has been characterised by rapid growth, fast-moving technology and the emergence of a global supply chain in which Asian companies now play an important and, in some parts of the market, dominant role.

The transistor is a device that amplifies or switches electrical signals. It was invented in the US and used initially as a replacement for the vacuum tube in radio and TV sets and other electronic products. The material used in the early days was germanium, now largely replaced by silicon, although other materials, called compound semiconductors, are being used in a growing number of high-tech applications.

The technology was quickly taken up in other countries, principally by electronics companies such as Siemens in Germany, Philips in the Netherlands, and GEC, Plessey and Ferranti in the UK. The invention at the end of the 1950s of the integrated circuit, a technique for placing an entire electrical circuit on a single silicon wafer, opened up a range of applications in new areas, including computers. During the 1960s and 1970s American companies, helped by large orders from the government for the use of semiconductors in defence equipment and space exploration, established a clear lead over their international rivals.[2]

In the early days production was mostly in the hands of companies such as IBM and A T & T, which used the devices in their own equipment. As the market expanded it attracted new entrants who set themselves up as merchant producers, making semiconductors for external customers. The most successful of the newcomers was Intel, founded in 1968. One of its co-founders was Gordon Moore, author of what came to be known as Moore's law; this was the prediction, which proved correct, that the number of transistors in an integrated circuit would double every two years.

Intel led the way in the next major advance, the microprocessor, which became the "brains" of the personal computer. The Intel x86 architecture, introduced in 1978, was adopted by virtually all computer makers, along with Microsoft's Windows operating system - hence the so-called Wintel monopoly.

Microprocessors and memories (used for digital data storage) drove the growth of the industry during the 1970s and 1980s, and again the American producers were far ahead of their international competitors. Some of them used their advantage to build semiconductor plants in

2. Franco Malerba, The semiconductor business, the economics of rapid growth and decline, Pinter 1985.

Europe, and European companies continued to lose market share.

The first challenge to US leadership came from Japan. The principal semiconductor makers were the big electronics companies – manufacturers of computers and telecommunications equipment such as NEC and Fujitsu, and consumer electronics firms such as Matsushita and Sony. As they mastered the technology, increased the scale of production and improved the manufacturing process, they were able to make semiconductor devices, mainly memories, at a cost below that of the American producers. They began to export to the US at a rate which alarmed the American industry - and the US government, which was worried that the decline of the semiconductor industry would have serious consequences for national defence. The result was a lengthy trade dispute which ended in 1986 with an agreement by the Japanese to raise prices and to provide greater access for American suppliers in Japan.

During the dispute the US government, in an unusual foray into industrial policy, helped to finance the creation of a technology consortium known as Sematech, whose aim was to restore US leadership in semiconductors.[3] However, the subsequent revival of the industry was mainly due, not to government support, but to the redirection by most American companies, and by Intel in particular, away from memories to microprocessors, where the US had a technical advantage.

Meanwhile other things were happening in Asia, outside Japan, which were to have profound consequences for the industry. Since the 1970s some American companies had been moving labour-intensive parts of the manufacturing process, principally assembly and packaging, to low wage countries. Taiwan and South Korea were favoured locations, and governments in these two countries used these assembly plants as the starting point for building their own semiconductor industries.

In South Korea Samsung, one of the diversified groups which dominated most sectors of the economy, was the first to take the plunge into semiconductors. In Taiwan, individual entrepreneurs played a bigger role. The most spectacular winner was Morris Chang, who had spent twenty years working for Texas Instruments in the US before returning to Taiwan in 1987 to found a new company, Taiwan Semiconductor Manufacturing Company (TSMC). Chang's plan was not to compete directly against companies such as Intel, but to create a foundry that would serve all semiconductor makers - not making chips of its own design but to the design of its customers.

This foundry model, which was later followed by Samsung, proved extraordinarily successful, thanks to Chang's willingness to invest on a massive scale (helped by the Taiwan government) in constantly improving the manufacturing process. TSMC became the acknowledged world leader in making the smallest, most technically complex and most powerful chips. Other foundries were built, mostly in Asia and to a smaller extent in Europe and the US, but none of them were able to match TSMC. Samsung was the closest competitor, and these two companies came to dominate the production of leading-edge chips.

3. Laura D'Andrea Tyson, Who's bashing whom? Trade conflict in high-technology industries, Institute for International Economics, 1992.

The consequence was to encourage the rise of a new type of semiconductor firm, one that concentrated on chip design and relied on the foundries for fabrication.[4] Design is a research-intensive, high-value activity, and the fabless model was taken up by many American firms, some of which, such as Broadcom, Qualcomm and Nvidia, built large and profitable businesses. Others, like Intel, stuck to the old model, designing, making and selling their own chips; they were known as integrated device manufacturers (IDMs),

This change in the structure of the industry coincided with, and contributed to, a shift of semiconductor production away from Europe and the US to Asia. Another factor was the growing concentration in Asia of the world's production of electronic consumer goods such as mobile phones and other handheld devices. These were industries that needed advanced semiconductors in large volume, and they attracted not only new fabs, but providers of the materials, equipment and services that formed part of the manufacturing process.

What has emerged is a complex global supply chain which for the most part has worked extremely well. Many countries are involved in the chain, each of them specialising in areas where they have developed a competitive advantage. The US is still the leader in terms of innovation, but it relies on other countries for many activities – materials, wafer fabrication, assembly, packaging and testing, and some key manufacturing equipment. About 75 per cent of world semiconductor production capacity is located in East Asia (including Japan, South Korea and Taiwan) and mainland China. The US share is down to 12 per cent.[5]

This dependence on distant suppliers involves risks. A recent study has shown that across the supply chain there are several regions which account for more than 65 per cent of the total global supply of a particular component.[6] If a key supplier in one of those regions is knocked out, whether through earthquakes, infrastructure failures or cyberattacks, it could bring parts of the industry to a standstill. There is also the looming problem of geopolitical tension, arising from the conflict between the US and China. The most obvious worry is over Taiwan.

Greater awareness of these risks has caused the US and the European Union to look for ways of achieving, not self-sufficiency in semiconductors, but a stronger home-based capability. In the US the focus is on encouraging investment in manufacturing, both by American companies such as Intel and by international producers. Both Samsung and TSMC are building plants in the US.

In the European Union, where the concept of "strategic autonomy" has been gaining ground, there is a particular emphasis on creating the capacity to make leading-edge chips of the sort that are made in Taiwan and South Korea. The three big European producers, Infineon in Germany, NXP in the Netherlands, and the Franco-Italian group, ST Microelectronics, mainly supply less technically advanced chips to the car makers and other industrial customers.

Since 2018 the European Commission has been engaged in an ambitious

4. Richard N. Langlois and W. Edward Steinmueller, The evolution of competitive advantage in the worldwide semiconductor industry 1947-1996, in David C. Mowery and Richard R. Nelson (eds), Sources of industrial leadership, Cambridge 1999.
5. Strengthening the global semiconductor supply chain in an uncertain era, Boston Consulting Group and Semiconductor Industry Association, April 2021
6. Strengthening the global semiconductor supply chain.

programme in microelectronics, classified as an Important Project of Common European Interest (IPCEI), which allows national governments to support their industries with subsidies that are partially exempt from state aid rules. Earlier this year the Commission unveiled a European Chips Act, which aims to increase Europe's share of the global market to 20 per cent by 2030 and to support investment in large, modern fabs for leading-edge chips. If Intel proceeds with its recently announced plan to build a large fab in Germany, that will give a boost to the Commission's plans.[7]

7. Peggy Hollinger and Richard Waters, Intel pours €30bn into chip manufacturing in Europe, Financial Times, March 15, 2022.

3. The UK semiconductor industry

The Johnson government's current review of semiconductor strategy is taking place after a long period in which the industry has attracted little attention in Westminster or Whitehall. Even after the revival of industrial policy by the 2010-2015 coalition government, this industry was not regarded as a high priority. The same was true of the more ambitious industrial strategy launched by Theresa May in 2017. The industry as it exists today is almost entirely the product of entrepreneurial effort, and in some areas that effort has been remarkably successful. The question now is whether the government should adopt a more active stance and, if so, what form any intervention should take.

The decline of semiconductor manufacturing

In the early years of the industry, following the invention of the transistor, British electronics companies were actively involved in the new technology, producing transistors for use in their own products and for outside sale. As the industry grew, and especially after the invention of the integrated circuit, they began to lose ground to the Americans. The British firms were reluctant to invest in the technically demanding, high-volume end of the industry – principally memories and microprocessors – where US firms were strong, and largely concentrated on low-volume semiconductors for specialised applications such as defence md telecommunications.

The marked the start of the decline of semiconductor manufacturing in the UK. The first attempt to arrest the decline was made by Harold Wilson's Labour government, which held office between 1974 and 1979. The government set up an industrial agency, the National Enterprise Board, which believed that the semiconductor industry was strategically and economically important, and that the UK should not rely for its supplies on imports from the US or investment in the UK by non-British companies.[8]

In 1978 the government funded the creation of a new firm, Inmos, which had developed a novel approach to the design of memories and microprocessors, based on what was called the transputer. The hope was that, if this approach was successful, Inmos could become a significant player in the world market. The company set up its headquarters and design centre in Bristol, with a manufacturing plant in Newport, South Wales.

Created by government and dependent on support from the taxpayer,

8. W. B. Willott, The NEB's involvement in electronics and information technology, in Charles Carter (ed), Industrial policy and innovation, Heinemann 1981.

Inmos did not find favour with Margaret Thatcher, whose Conservative administration took office in 1979. In a decision that was widely criticized in the scientific community, the business was sold to Thorn, a British electronics company, in 1984, and resold five years later to the Franco-Italian group, SGS Thomson (later renamed STMicroelectronics).[9]

By the start of the new millennium British-owned firms had largely opted out of mainstream semiconductor production, although there were some small fabrication plants serving niche markets.[10] Yet there were other parts of the industry where the UK did have considerable strengths, and that had happened, in part, as a by-product of the Inmos investment.

The South West cluster

Despite Inmos's short life as an independent company, its Bristol design office (which continued to function until it was closed by ST Microelectronics in 2013) became a productive centre for semiconductor-related research. The 1980s and 1990s saw the birth in the Bristol area of numerous design firms, based on the fabless model, many of which were founded by ex-Inmos technologists. The south-west semiconductor cluster, sometimes known as Silicon Gorge, was seen as an example of how a high-growth, science-based industry, closely linked to local universities, could take shape in the UK.[11]

One company founder was David May, the principal architect of the Inmos transputer and designer of the programming language, Occam, which was associated with it; he continued to work for Inmos after it had been acquired by ST Microelectronics. In 1995 he was appointed professor of computer science at Bristol University, and it was from there that he helped to start several new firms. One of them was Xmos, which developed what were called Software Defined Silicon (SDS) chips, designed to be easily programmed and to support the design of innovative consumer electronics products. Xmos supplies chips to makers of digital audio equipment and has recently introduced devices for machine learning to enable voice and image recognition.

The region has spawned many start-up firms and several new design centres. One of the most successful serial entrepreneurs has been Stan Boland, who spent several years with Acorn Computer in Cambridge before founding Element 14, a fabless company that was later sold to Broadcom of the US for $594m. Together with Nigel Toon, he also co-founded Icera, which established itself as a credible rival to a much larger American firm, Qualcomm – so credible as to induce Qualcomm to engage in aggressive tactics in an attempt to weaken it. (Qualcomm was later fined by the European Commission for antitrust violations). In 2011 Icera was sold to Nvidia for $367m.

Nigel Toon had spent thirteen years with Altera, a Silicon Valley semiconductor firm, before returning to the UK at the end of the 1990s. He is now running Graphcore, which has developed what it calls Intelligence Processing Units, designed for artificial intelligence and machine learning. It is a direct competitor to Nvidia, and, like Nvidia, its

9. The sale of Inmos was described by one critic as an example of the government's "reluctance to play a part in identifying and supporting the technologies that may have strategic value, whether in terms of supply security or their potential economic importance in the future", William Walker, National Innovation Systems: Britain, in Richard R. Nelson (ed), National Innovation Systems, a comparative analysis, Oxford 1993.
10. During the 1980s and 1990s a number of fabs were built by non-British firms, notably in Scotland in what was called Silicon Glen, and in the north-east by Siemens and Fujitsu, but by the early 2000s most of these firms had pulled out.
11. Louise Marston, Shantha Shanmugalingam and Sion Westlake, Chips with everything: lessons for effective government support for clusters from the South West semiconductor industry, Nesta, November 2010.

chips are manufactured by TSMC in Taiwan.

Graphcore employs some 600 people, based in Bristol, Cambridge, Oslo, and Gdansk. It has attracted funds from a wide range of investors, including venture capital firms such as Sequoia in the US as well as industrial companies such as Microsoft, Samsung and BMW. In its most recent funding round, at the end of 2020, it raised a further $222m, bringing the total amount raised from outside investors to $730m; its valuation at that point was $2.8bn. It has had no direct support from the government.

Graphcore has done well, but it is a minnow compared to Nvidia, which has 22,000 employees and a market capitalisation of around $400bn. There is an obvious question as to whether it can continue to grow as an independent company or will be bought by a larger competitor. It may be some time before it decides to go public, and if and when it does so it will have to decide whether to list in London or New York. The apparent inability of the London Stock Exchange to attract technology-based firms such as Graphcore has long been seen as a flaw in the British financial system, making it difficult for the UK to foster a vibrant high-technology sector comparable to that of the US. On this issue the current focus of anxiety is on the UK's most successful semiconductor firm, which is discussed in the next section

The rise of ARM

The starting-point for ARM was a microprocessor that was developed in the early 1980s by Acorn, a Cambridge-based microcomputer company. Acorn was part of the Cambridge high-tech cluster, sometimes known as Silicon Fen. One of its founders was Hermann Hauser, an Austrian-born physicist who later became a successful venture capitalist and an influential advocate for the high-tech community.

Acorn had some success in selling its innovative computers - endorsement by the BBC gave a useful boost to the business - but it made the mistake of attacking too many different markets ; it also made an ill-judged foray into the US.[12]

As Hauser and his colleagues looked for ways of improving the performance of their machines, they conceived the idea of developing their own microprocessor based on a novel architecture, known as Reduced Instruction Set Computing (RISC), which had been recently introduced in the US. The first Acorn computer with this design was launched in 1985.

At that time Acorn was in financial difficulty and had to be rescued by a capital injection from Olivetti, the Italian electronics company. There was also a view inside the company that the microprocessor unit, which was attracting interest from other computer makers, might do better as an independent firm.[13] A crucial event was the decision by Apple to use Acorn's architecture in a new handheld device, the Newton Notepad. This led to an agreement in 1990 between Acorn, Apple and Olivetti to set up a new company, initially known as Advanced RISC Machines, later renamed ARM.

12. Suma Athreye, Agglomeration and growth, a study of the Cambridge high-tech cluster, in Timothy Bresnahan and Alfonso Gambardella (eds), Building high-tech clusters: Silicon Valley and beyond, Cambridge 2004.
13. Elizabeth Garnsey, Gianni Lorenzoni and Simone Ferriani, Speciation through entrepreneurial spin-off: the Acorn-ARM story, Research Policy 37, 2008.

As an independent company without manufacturing capacity of its own, ARM might have outsourced the production of microprocessors while retaining control of marketing and distribution. Instead, it decided to license its intellectual property either to semiconductor makers or to firms such as Apple that used its designs in their products, thus avoiding the costs involved in marketing. This strategy proved extraordinarily successful. By 2001 the design had been licensed to nearly 200 semiconductor companies. Just as the Intel microprocessor had been dominant in personal computers, the ARM architecture became the standard in smartphones and other hand-held equipment. Unlike Intel, ARM was not a manufacturer.

ARM was the undoubted star of the British high-technology sector; it showed that a world-leading semiconductor company could be built from a UK base - and it had done so without government support. Hence it came as a shock when in 2016 ARM agreed to be taken over by SoftBank, an ambitious Japanese investment group which was building a portfolio of high-technology businesses; the price was $32bn.

The British government raised no objection to the deal, which it saw as a way of injecting capital into ARM and enabling it to attack new markets. Four years later, however, the Japanese owner decided to withdraw from ARM and to sell the company to Nvidia. This proposal was referred to the Competition and Markets Authority (CMA), which concluded that the merger would lead to a substantial lessening of competition. The principal risk, in the CMA's view, was that the combined company would discontinue the open licensing policy on which the British company had relied and prevent other firms from accessing ARM's designs and intellectual property.[14] There was also concern about the impact of the proposal on national security, prompting the government to invoke the 2002 Enterprise Act, which allows the authorities to block mergers on grounds other than competition.[15]

The proposed merger was criticised by some of ARM's customers, notably Qualcomm in the US, and by leaders of the British high-tech community. Hermann Hauser argued that the sale to Nvidia would have serious implications for the UK's economic and technological independence, "Not only do we lose one the few remaining weapons at our disposal in global trade negotiations, but we are handing it to one of the two adversaries in the US-China trade war, with the realistic consequence that Britain becomes collateral damage in this war."[16] Hauser suggested that the government should put together a syndicate of ARM licensees and institutional investors to take the company public, and that the government should retain a golden share in order to prevent any unwanted takeover.

In the face of this opposition Nvidia withdrew from the deal, and SoftBank then decided to refloat ARM on the stock market. But this did not end the debate. The argument shifted to whether the flotation of ARM would take place in the US or the UK. Tom Tugendhat, chairman of the Commons Foreign Affairs Committee, argued that in the interests of national security, and to protect the country's science and technology

14. NVIDIA-Arm, A report to the Secretary of State for Digital, Culture, Media and Sport on the anticipated acquisition by NVIDIA Corporation of Arm Limited, Competition and Markets Authority, July 20, 2021.
15. DCMS, Proposed acquisition of ARM Ltd by NVIDIA Corporation: Consultation on Phase 2 reference. November 16, 2021.
16. Evidence submitted by Hermann Hauser to House of Commons Foreign Affairs Committee, October 2020.

base, the government should ensure that the company was listed in London.[17] Like Hauser, he suggested that the government should acquire a golden share in the company. SoftBank had made no decision on where the flotation would take place when this paper was written.

The China factor

The row over the threatened ARM takeover by Nvidia came at a time when, for other reasons, the British government was adopting a more sceptical approach to foreign takeovers. Under the National Security and Investment Act, which came into force in January 2022, the government was given the power to scrutinise and where necessary to block transactions – not only acquisitions but also purchases of large shareholdings or of intellectual property – which caused a change of control in companies deemed to be important for national security.

The legislation is partly modelled on America's Committee on Foreign Investment in the US (CFIUS), although, unlike CFIUS, it applies to domestic as well as foreign acquisitions. It covers seventeen industries, including advanced materials, computer hardware, artificial intelligence and quantum technologies. Change of control transactions in these industries have to be notified to the government before completion. Where the government thinks there is a possible risk to national security it can call in the transaction for review. It then has three options: to clear the transaction; to order the parties to abandon it; or to grant approval subject to conditions. The government may also act retrospectively; transactions that took place between November 2020 and January 2022 can be challenged.

In the years leading up the Act there had been growing concern, in Parliament and elsewhere, that successive governments had been too relaxed about Chinese acquisitions in high-tech industries. This concern made itself felt in 2017, when one of the UK's leading semiconductor design companies, Imagination Technologies, was taken over by a venture capital firm, Canyon Bridge, which was backed by Chinese investors. There were calls for government intervention, notably from Tom Tugendhat, who had long been warning about Chinese intrusion in sensitive industries. His committee conducted an inquiry to establish whether the sale had implications for national security.[18]

Since its creation in 1985 Imagination had achieved some success as a supplier of graphics technology for video games, and it then transplanted these designs into the mobile phone market. It went public in July 1994 and at the height of the dot com boom at the end of that decade its market capitalisation exceeded $1bn. With a business model similar to that of ARM, its customers included many of the world's leading semiconductor companies; it also had a close relationship with Apple, which became its biggest customer. That relationship came to an end in 2016 when Apple announced that it would no longer use Imagination's intellectual property. That decision plunged the company into a financial crisis, the outcome of which was the sale to Canyon Bridge.

17. Tom Tugendhat, The government must stop Arm's "pass the parcel" treatment and invest, Financial Times, May 16, 2022.
18. House of Commons Foreign Affairs Committee, Evidence from Imagination Technologies, May 5, 2020

What followed was a period of uncertainty during which the government showed interest in what Canyon Bridge might do with the company, although it had no power at that time to block the deal. There were also several changes in top management and some confusion about the future direction of the company.

In 2020 the owners appointed a new chief executive, Simon Beresford-Wylie, who had long experience as a senior manager in high-technology businesses and had worked closely with private equity firms. Under his leadership the management team was strengthened, the financial situation was stabilised, and a clear strategy was adopted. An important decision was to take up an open-source technology known as RISC-V and to offer it as an alternative to ARM; it allowed smaller developers and manufacturers to design and build hardware without the cost of licensing proprietary architecture and paying royalties.

By this time anxiety about the Chinese connection appeared to have subsided. Beresford-Wylie made it clear that the company would continue to invest in the UK and maintain its commitment to research. It would have links with China, but this was mainly because of its importance as a market; China accounted for some 35 per cent of the company's revenue, about the same as the US. According to the company, the principal investor in Canyon Bridge, China Reform Holdings, did not interfere in the running of the business; contact consisted mainly of a one-hour conversation every three months between Beresford-Wylie and a China Reform executive. That arrangement would come to an end when Imagination was listed on the stock market, which was likely to happen within the next two years.

Compound semiconductors in South Wales

The China factor has affected another part of the semiconductor industry, and this case has sparked a political controversy which is still continuing. The starting-point was the takeover by a Chinese-controlled group in July 2021 of Newport Wafer Fab, a semiconductor factory in South Wales.

The origins of this story go back to the creation of Inmos. The Inmos production plant in Newport started making silicon wafers in 1982 and it continues to operate today. After the sale of Inmos to Thorn in 1984 the plant went through several changes of ownership before becoming part of Infineon, the German semiconductor company, in 2014.[19] Infineon's interest was mainly in products based on a compound semiconductor technology called gallium nitride, which had been developed at Newport by the previous owner. Three years later Infineon transferred this technology to its advanced products factory in Austria and put the Newport plant up for sale. It was sold in a management buy-out, partly financed by a £13m loan from the Welsh government; the company was renamed Newport Wafer Fab (NWF).

The head of the buy-out team was Drew Nelson, an entrepreneur who over the previous four years had played a leading part in establishing what became known as the Compound Semiconductor Cluster. Nelson was a scientist who had held senior positions in BT's research laboratories

19. Infineon had taken over International Rectifier, which had owned the Newport site since 2002 and used it as its global R & D and advanced product manufacturing site.

in Martlesham, Suffolk. In 1988 he left BT to set up his own company, initially called Epitaxial Products International, based in Cardiff, to make compound semiconductor materials for optoelectronic devices. The company grew by acquisition during the 1990s; after merging with an American company in 1999 it changed its name to IQE and in the following year went public on the London Stock Exchange. It is now a leading supplier of advanced compound semiconductor materials, with plants in the US, Taiwan and Singapore as well as the UK.

Nelson conceived the idea that IQE could form the nucleus of a compound semiconductor cluster, providing an end-to-end supply chain to support users of this technology. It would bring together a group of South Wales firms that had an interest in the field and attract investment from other parts of the UK and from overseas.

Unlike silicon devices, compound semiconductors are made up of two or more elements from the periodic table – examples are gallium arsenide and gallium nitride – and they account for about 15-20 per cent of world semiconductor production; they are growing at about twice the rate of the overall semiconductor market. Although the manufacturing process is more complex than that of silicon chips, they have several advantages over silicon, including lower power consumption; they are suitable for a wide range of applications such as electric cars and high-speed fibre optic data links.

Nelson's first step, in 2015, was to form a partnership with Cardiff University to promote the commercialisation of compound semiconductor research. They created the Compound Semiconductor Centre, which would constitute the research base for the cluster that Nelson had in mind. Swansea University was brought in later, and both universities invested in new laboratories and "cleanroom" facilities. Alongside IQE, the cluster embraced several South Wales firms which had some involvement in compound semiconductors; other companies established design centres in the region.

The Welsh government had been a supporter of the cluster from the start, and that support was reinforced by grants from UK Research and Innovation (UKRI), the UK government's research funding agency. In 2016 Innovate UK, which is part of UKRI, set up the Compound Semiconductor Applications Catapult to encourage commercialisation.

Nelson and his colleagues had the ambition to create what would become Europe's fifth semiconductor cluster, alongside the four established clusters – Dresden in Germany, Grenoble in France, Leuven in Belgium and Eindhoven in Holland – and the only one of the five to focus on compound semiconductors. The eventual goal was that the South Wales cluster should play the same sort of role in compound semiconductors that Taiwan's TSMC had done in silicon.

Nelson was eager to take part in European semiconductor programmes, and when the Commission launched its IPCEI for microelectronics in 2018, the cluster was welcomed as a credible participant. IQE and other cluster members joined a ten-company partnership which was to handle the compound semiconductor part of the programme. However, this participation needed financial support from government. The Brexit vote and the subsequent election of Boris Johnson's government undermined whatever enthusiasm there had been for industrial collaboration with the EU. By declining to provide the funds needed for UK companies to participate – the amount was £48m - the government effectively brought to an end the UK's active involvement in the IPCEI programme.

The Newport Wafer Fab takeover

When NWF was established in 2017 as an independent company, the objective was to develop it as an open access foundry serving customers in the UK and overseas. Its business at the time of the buyout consisted of silicon-based semiconductors, with Infineon as the only user. While these Infineon orders were worked through, the plan was gradually to replace them with higher-value products based on compound semiconductors. To keep the factory fully employed while this process was getting under way, NWF secured orders from other silicon chip customers.

One of these customers was Nexperia, a large Dutch company which needed additional capacity for its power semiconductor devices. In July 2019 NWF and Nexperia made an agreement whereby a fixed proportion of Newport's capacity would be allocated to Nexperia in return for an injection of capital and the acquisition by the Dutch company of a 14 per cent shareholding. There were other provisions in the agreement, one of which gave Nexperia the right, if NWF were to face financial difficulties, to purchase the other 86 per cent of the equity.

Nexperia is not in the foundry business; it is an integrated design manufacturer (IDM), designing, making and selling its own semiconductors in high volume. Its biggest customer, accounting for nearly half its sales, is the motor industry. In addition to its stake in NWF, it has wafer fabrication plants in Manchester and Hamburg as well as test and assembly factories in Asia.

Nexperia had originally been part of Philips, the Dutch electronics group. In 2006 Philips had put its semiconductor division into a separate company, NXP, which was itself split up ten years later when its standard products business was divested and given the Nexperia name. The divestment took the form of the sale of that business to a group of Chinese investors.

At the end of 2019, some months after the NWF agreement, these Chinese investors sold Nexperia to Wingtech, a Shanghai-listed company which is one of China's largest original design manufacturers (ODMs). (These are firms that design and make mobile phones and other electronic equipment for brand-name companies such as Samsung or Apple). Wingtech, a Nexperia customer, was then in the process of building up its semiconductor business, through acquisitions and by building a large fabrication plant in Shanghai.

During 2019 the Nexperia/NWF arrangement appeared to be working satisfactorily, but NWF was hit hard in the early months of 2020 by a collapse in orders, resulting from the Covid pandemic. It was forced to cut back production and for several months the factory operated far below capacity. Then, in the second half of the year, demand recovered suddenly and sharply. To get back to full production, NWF needed more working capital. Strenuous efforts were made to find new sources of finance, but these were ultimately thwarted. Nexperia then made an offer to take over the company. Since the alternative was to put the company into administration (with the loss of 450 jobs), the directors had no option but to accept the offer, and the deal went through in July 2021.

What followed was a public debate, involving the government and senior Conservative politicians as well as the parties directly concerned, about the pros and cons of the Nexperia takeover. The government's initial view was that any adverse effects that might result from the deal were not serious enough to warrant intervention. There were, however, several Conservative members of parliament, led by Tom Tugendhat, who took a different view. In a report published soon after the acquisition Tugendhat's Foreign Affairs Committee described the takeover as "the sale of one of the UK's prized assets to a strategic competitor at a time when global chip shortages mean that products manufactured by NWF are of vital national importance". In subsequent reports the committee referred to China's ambitions to achieve self-sufficiency in semiconductors, the probable transfer of technology to Wingtech, and the possibility that the new owners might shift production from Newport to China.[20]

In response to this pressure, the government asked the National Security Adviser, Sir Stephen Lovegrove, to review the acquisition. In January 2022, while this study was under way, the NSI Act came into force, giving the government the power to investigate the Nexperia deal, and, if it was found to be pose a risk to national security, to force the acquirer to abandon it. On May 25 Kwasi Kwarteng, Business Secretary, announced that, using his powers under the Act, he would call in the Nexperia/NWF merger for review. He has thirty days in which to consider the matter, although this can be extended by forty-five days.

In the lobbying that has surrounded the NWF affair, opponents of the takeover have argued that the transfer of control to Nexperia will frustrate any hope of developing the plant as an open access foundry for compound semiconductors, and thus damage both the South Wales cluster and the British semiconductor industry.

The change of ownership, the argument continues, will hold back the development of compound semiconductor technologies, one of the few areas of the industry where the UK has a competitive advantage. It will also force some customers to switch to overseas suppliers for the manufacture of their chips. For example, Rockley Photonics has partnered with NWF for the specialised wafer processing that it needs for the manufacture of wearable health sensors, a market in which it has a leading position. When that contract comes to an end, Rockley will use American and European suppliers for silicon wafer processing. Part of the team will remain within the cluster, focussing on the integration of compound semiconductor

20. The Commons Foreign Affairs Committee published several reports on the issue, including "Sovereignty for sale: follow-up to the acquisition of Newport Wafer Fab", March 29, 2022.

components with the silicon photonic wafers.

Nexperia's case is that under its plan for the business, which involves substantial investment in expansion and modernisation, it will build NWF into a major supplier of chips to the world semiconductor industry, creating an asset which will complement the cluster. The company points out that Nexperia and its predecessor companies have been investing in the UK for many years – the Manchester plant was built in 1970 - and it is continuing to do so. In South Wales it is working closely with local schools and universities in providing apprentice training and in supporting research. As for national security, the company says that the Newport factory will provide additional capacity for commonly used chips, not advanced technology, and that there is no intention to be involved in work that has a military or security application. It insists that Nexperia is a European company; Chinese ownership has not affected its business policy, or its participation in European semiconductor programmes.

Nexperia's interest in NWF is in the silicon side of the business. At the time of the take-over NWF was involved in several development projects on compound semiconductors, and the two companies discussed a proposal whereby these activities might be spun off into a separate company, located in a part of the Newport site which was under-used; the aim, according to a joint press release, was to preserve the key initiatives of the Compound Semiconductor Cluster. This idea appears to have made little progress; it was not clear at the time this paper was written whether a scheme along these lines was still on the table.

4. What should the government do?

The government is facing two decisions: whether to use the NSI powers to order a reversal of the Nexperia/NWF acquisition, and what action it might take to support the UK semiconductor industry as a whole. The first will be made in the next few weeks; the second will await the completion of the DCMS study of the industry, which is expected before the end of the year.

National security

Ministers have made it clear that the National Security and Investment Act is focussed solely on national security; it is not an instrument of industrial policy. In the NWF case national security concerns focus on two main issues: the risks associated with Chinese ownership, and the damage that the takeover might do to the Compound Semiconductor Cluster and by extension to the UK semiconductor industry.

Those who believe that the Nexperia takeover should be blocked argue that Chinese ownership is dangerous for several reasons. First, Chinese ownership of two of the country's main wafer fabrication plants, Newport and Manchester, will make the UK a less trusted partner in the eyes of countries with which the UK needs to cooperate in handling supply chain issues.

Second, the defence-related technologies on which NWF has been working will pass into the hands of a hostile power. Several of NWF's ongoing projects (which started when the company became independent and have continued under the transitional arrangements agreed with Nexperia) fall squarely within the seventeen industries listed in the NSI Act as being sensitive in terms of national security. There is particular concern about compound semiconductor technologies that are used in the manufacture of photonic, communications and power systems, all of which have dual-use in security and defence.

Third, there is a strong possibility that when Wingtech's Shanghai plant reaches full capacity the company might close Newport and shift production to China, thus supporting China's drive to reduce semiconductor imports,

A separate argument, not directly related to China, is that, by frustrating the development of NWF as an open access foundry, the acquisition removes an essential building block in the creation of a semiconductor cluster that could become extremely valuable to the British economy – and to national security. To take one example, defence-related companies that use compound semiconductors would be forced to have their chips made overseas, with the danger that they will lose control of their intellectual property. To replace NWF by building a new open access foundry from the ground up would be expensive and take some years to bring into production.

Mr Kwarteng will have to weigh these points -- most of which are strongly contested by Nexperia -- against the argument that, through the NWF acquisition, a large, well-regarded semiconductor company, with a long record of investing in the UK, is injecting capital and technology into a factory that needs to be modernised and providing it with access to a wide range of international customers.

The Business Secretary's decision will be based, as it should be, on the facts of this particular case, assembled and analysed by the Investment Security Unit, the branch of BEIS that administers the Act. But the Nexperia/NWF affair gives the government an opportunity, which it should use, to set out its position on the wider issue of China's involvement in the British economy.

The fact that the words "strategic" and "national security" can be defined in several different ways gives the government flexibility, but it also makes for uncertainty in the minds of firms and investors who may be contemplating acquisitions. What counts as a strategic asset? Some might argue that, in view of the clear evidence that China is using overseas acquisitions as a means of strengthening its industrial/military capabilities, any Chinese ownership, partial ownership or significant investment in any of the industries covered by the NSI Act should be regarded as unacceptable. If that is the government's position, it should be spelt out. How far that approach might be extended to non-NSI industries (for example batteries for electric cars, where the principal UK-based producer is Chinese-controlled) could also be usefully clarified.

The future of the industry

On the second question that the government is considering – does the UK need a strategy for semiconductors? - the answer has to start from the recognition that the UK semiconductor industry is part of a globally interdependent production system in which no country, even one as large as the US, can hope to be self-sufficient. This puts anxiety over the semiconductor supply chain, which was part of the reason for the Johnson government taking an interest in the sector, into perspective.

The present shortage stems largely from the collapse in demand from some semiconductor-using industries, notably the car makers, in the early months of 2020 when the Covid epidemic struck. At the same time other industries, notably makers of consumer electronics products, saw demand grow sharply. Suppliers of semiconductors to the car makers and other "just-in-time" manufacturing industries (many of which are in Europe) had to cut back production and put expansion plans on hold; there was no way of knowing how long the dearth of orders would last. When demand recovered in the second half of 2021, it did so suddenly, and suppliers found themselves with a surge of orders which they could not fulfil.

The semiconductor industry is notorious for swinging between periods of over- and under-supply. The current shortage, which is expected to ease next year, is a temporary crisis and does not by itself call for radical changes in the way the supply of semiconductors to the UK is organised. There may be ways of reducing supply chain risks, through deeper relationships with overseas suppliers and where possible avoiding reliance on a single source. For the UK, given its weak position in the manufacturing side of the industry, it is not feasible to emulate the US and the European Union in their plans for investing on a very large scale in new semiconductor manufacturing capacity - although there is certainly a case for closer cooperation with the US and the EU to ensure security of supply. In theory the government could support, directly or indirectly, the production in the UK of semiconductor types that are thought to be crucial for national defence, but they would have to be combined with other types that could only come from overseas.

The world semiconductor industry involves many different countries, hundreds of different components and processes and many different companies. UK firms need to be integrated into the global system, working with overseas partners and having access to the latest technology. This is not an industry which provides much scope for national champions, nor does it lend itself to the kind of industry-specific strategy that has been introduced in the UK for other sectors. For example, the Faraday programme for batteries, launched in 2017, had a clear, narrowly defined objective: to foster the creation of a viable battery supply chain to support the UK-based car makers as they made the transition to electric cars. Any strategy for semiconductors would have to be broader in scope, and it is not clear how the objectives would be defined.

Because the industry is so diffuse, it provides opportunities for entrepreneurs to identify sectors where barriers to entry are low. The success of the Compound Semiconductor Cluster, conceived by Drew Nelson, shows that it is possible to compete from a UK base in a sector that lies outside the mainstream of the industry.

In a different part of the market, PragmatIC Semiconductor was founded with a small team in Cambridge in 2010. It makes flexible, low-cost integrated circuits for a variety of applications including RFID products (radio frequency identification). This company operates as a foundry, but the technology, and the capital cost of production, are quite different from the traditional silicon foundries in Asia. PragmatIC, which recently announced plans to build a second fabrication plant in Durham, is a world leader in its field. While the company has global ambitions and plans to build fabs outside the UK in coming years, the Durham factory will remain the heart of the business and its technology base.

Opportunities for new entrepreneurial ventures are likely to increase in coming years as the industry changes. Moore's law is reaching its limits and some scientists believe that the UK, with its expertise in design, advanced materials, compound semiconductors and photonics, could make a leap forward in the new technologies - for example in heterogeneous integration[21] - which will take shape in the post-Moore era. This could involve more investment in manufacturing, at an affordable scale, to create a more complete supply chain for those products in which UK-based firms have a competitive advantage. There could also be innovation in manufacturing processes, reducing the industry's dependence on Taiwan-style "mega-fabs".

The government should build on the industry's strengths, as it has done with compound semiconductors. It should encourage new entrants and help them to scale up. Given the importance of the industry, there is a case for stepping up the support that is provided through UK Research and Innovation, probably with a greater emphasis on later-stage development. But the future evolution of semiconductor technology in the post-Moore world is unpredictable, and the government should be wary of trying to steer the industry in a particular direction. Decisions on which development avenues are the most promising are best left to the private sector.

21. Heterogeneous integration can be described as the combination of dissimilar materials and components to create multi-featured, functional blocks or systems, EPSRC Centre for Power Electronics.

£10.00
ISBN: 978-1-913459-94-9

Policy Exchange
1 Old Queen Street
Westminster
London SW1H 9JA

www.policyexchange.org.uk