The future of the UK's semiconductor strategy

An alternative to onshoring: strategic interdependency

Imagination In partnership with Global Counsel

FOREWORD

Over the past two years, semiconductors have broken through into the public consciousness like never before. Much of this has to do with the ongoing global shortages of semiconductors, which have demonstrated the interlinkages of our globalised supply chains and disrupted trade and manufacturing in sectors from cars and smartphones to medical devices and solar panels.

Yet even prior to shortages, the industry had seen new pressure on the semiconductor supply chain driven by big transitions in the technologies we demand. These included more complex, high-tech cars with many displays and assistive driving features, a shift toward ever smarter products and a proliferation of devices using Artificial Intelligence (AI).

At Imagination's headquarters in Kings Langley, we have been proud to enable this transition, acting as the 4th largest supplier of semiconductor IP (Intellectual Property) globally, supporting 11 billion products worldwide and employing 800 people. However, we recognise that continuing technology advancements and the need to increase supply chain resilience will require the UK to adopt a holistic approach to its semiconductor strategy that looks beyond the needs of any one company.

This report begins that process by setting out a vision for a strategic UK approach to semiconductors, both in terms of its domestic industry and its wider role in the shared value chain. It rejects an approach based on massive investment in local manufacturing capacity, or 'onshoring', as is being pursued in other parts of the world.

Instead, the view taken in this report is that the UK should double down on its comparative advantage in semiconductor design, while simultaneously seeking to strengthen security of supply through new strategic international alliances in semiconductor production. It judges that the UK government has three key levers at its disposal: domestic research and development (R&D), IP policy, and trade diplomacy. Cutting across all three policy areas is the basic rationale that the UK should maintain an open and attractive investment environment, serving as a base from which semiconductor companies can scale and grow.

The recommendations that flow from this are intended as the starting point for a wider debate on the future of the UK's semiconductor strategy. With the government currently in the midst of an in-depth review of the UK's semiconductor sector, and with many of the UK's allies – and competitors – taking bold measures to shape the future of semiconductor manufacture and trade, now is the time to have that conversation.

Simon Beresford-Wylie
CEO Imagination Technologies

EXECUTIVE SUMMARY

The global shortage of semiconductors, which is expected to last into 2023, has triggered a belated awakening among policymakers to the importance of these critical technologies. Policymakers in the EU, US, Japan and elsewhere have recently proposed sweeping packages to increase supply chain resilience and support their domestic chip industries. These often put a strong emphasis on expanding local manufacturing through public subsidies and tax incentives.

Despite being one of the world's leading economies, the UK has been largely absent from this debate. In part this reflects the fact that it is not a major manufacturer of chips, either for itself or for the global economy. Yet its economy and industry have been just as affected by the shortages as those of other countries.

More fundamentally, the semiconductor supply chain involves more than just manufacturing; an extended process of research and development, commercialisation and design must take place before chips can be physically fabricated. It is in these areas where the UK excels, and where its future role in the global value chain for semiconductors lies.

For that reason, this report advocates a strategic UK approach to semiconductors that is driven by two fundamental aims:

1. Building and consolidating the UK's strengths in semiconductor design, further developing a comparative advantage that complements others' established strengths in wafer fabrication and assembly, testing and packaging (ATP).

2. Promoting a model of 'strategic interdependence', in which UK firms are strongly encouraged to deepen links with reliable, strategically aligned partners mutually committed to a shared value chain model.

A possible framework for identifying 'shared value chain' partners is proposed in the report, based on a set of indicators that could help assess the reliability of a strategic trade and production partner.

Several specific actions and policy recommendations result from this approach. Reinforcing the UK's existing leadership in chip design will mean ensuring that the UK is able to attract leading global talent and continued investment in cutting-edge R&D, as well as the commercialisation pathways needed to remain ahead of the pack. The IP that British semiconductor designers generate subsequently needs to be protected and promoted abroad, including by challenging unfair practices in export markets and supporting UK firms in securing fair conditions for the licensing of their IP overseas. Finally, to diversify its semiconductor supplies, the government should use trade diplomacy to encourage new sources of supply from like-minded countries, using its critical role in providing IP as a point of leverage.

Action across these areas will help to both cultivate UK home-grown innovation and bolster the UK as an investment environment for companies at the cutting edge of semiconductor technology. This builds on the UK's culture of invention, scientific discovery, world-leading universities, and – critically – openness to trade and foreign capital.

A STRATEGICALLY COHERENT UK SEMICONDUCTOR STRATEGY

Supporting R&D in the UK

Ensure the UK attracts the best global talent in the sector through the design of a new scale-up visa and the expansion of the Global Talent Network.

Use UK government institutions like ARIA to drive the most cutting-edge areas of R&D.

Fill the investment gap through the creation of a bespoke fund under the oversight of the British Business Bank or British Patient Capital that enables early-stage research to be commercialised in the UK.

Protecting and promoting UK IP abroad

Deepen engagement with strategic trading partners, exploring ways to support and expedite processes for licensing IP to partners in those jurisdictions.

Expand enforcement and cooperation on IPR registration and enforcement standards, especially through IP attaché networks.

Play a greater role in educating UK industry on how to commercialise and license IP, as well as how to utilise IP rights within contractual relations.

Championing diversification

Support the diversification of the UK's semiconductors chain through a body modelled on the TTC that convenes a group of strategically interdependent shared value chain partners on semiconductor trade and reinforces their cooperation.

Pioneer a common approach to export controls that recognises controls must be targeted, proportionate and justifiable.

THE SEMICONDUCTOR SHARED VALUE CHAIN

A UK semiconductor strategy must be built on a clear understanding of the global value chain for semiconductors and the UK's role within it. Semiconductors are uniquely intricate products, being both R&D-intensive to design and capital-intensive to manufacture. The result of this has been an increasingly specialised global supply chain, with different regions performing different roles based on their comparative advantages.

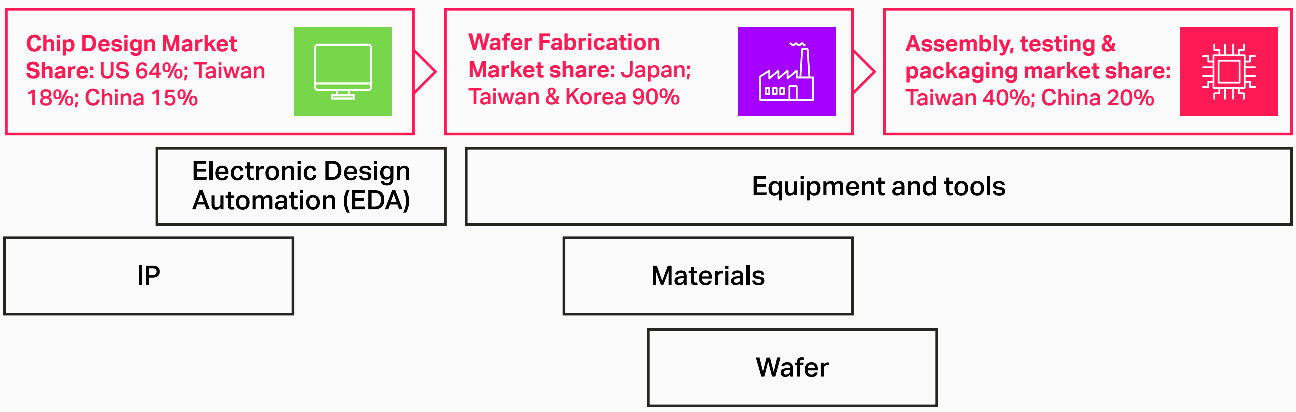
At a high level, there are three broad process steps in the supply chain: chip design, wafer fabrication and the combination of assembly, testing and packaging. These are underpinned by various elements that include IP, key materials, wafers themselves, and the advanced manufacturing equipment and facilities required for semiconductor production **(Fig. 1)**.

The specialisation at different stages shown in **Fig. 1** has intensified rather than reduced over time as the number of transistors - tiny switches that form logic circuits - that can be integrated into a silicon chip has grown rapidly. This rapid evolution in sophistication means that it has become nearly impossible for a single firm to specialise in every aspect of design and manufacturing. This in turn has led to a 'disaggregation' of the industry, as firms have emerged that specialise in specific parts of the sectoral value chain.

A key feature of this has been the emergence of fabless chip companies. These are firms who design and sell chips but outsource the manufacturing to third-party fabs or foundries. IP companies like Arm, Ceva and Rambus emerged to support these fabless companies, each a specialist in particular design elements, and licensing their innovations as blocks or cores of intellectual property to chip companies. A few chip companies, like Intel and Samsung, have retained the traditional vertical model of design and manufacturing but even these companies now routinely license technologies from third-party specialists.

This development of distributed capabilities in the semiconductor value chain has been indirectly supported by a combination of government incentives, the clustering of skills and expertise in specific regions and the concentration of capital flows. One of its consequences has been interdependencies between countries, which has meant countries must rely on one another to transfer knowledge, talent, IP, materials, and equipment around the world to the optimal location for performing each activity but the finished product, be that a car or a smartphone, is delivered and used around the world.

Fig. 1: The semiconductor value chain



THE IMPLICATIONS OF INTERDEPENDENCE

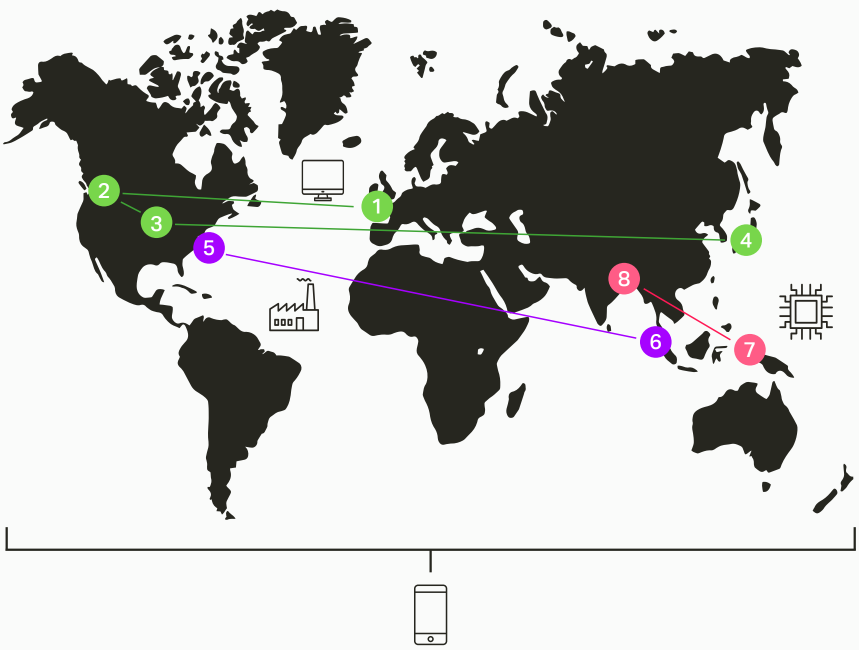
The structure of the production chain described in **Fig. 2** has enabled the wider semiconductor industry to deliver value, efficiency and targeted technical advances in semiconductors, while still producing high volumes at relatively low cost.

But it has also created specific vulnerabilities, as specialisation has led to the geographical concentration of certain supply chain elements. Some specific features of this are that currently 75% of manufacturing capacity is in China & East Asia, the U.S. has a 64% market share in chip design, and 85% of the smallest and most sophisticated chips are produced by a single Taiwanese company (TSMC).[1]

The extent of this specialisation and its implications were largely overlooked by policymakers, customers, and others in the supply chain until a combination of geopolitical tensions, accidents, natural disasters, and demand surges created significant shortages and delays in finished products like cars and laptops. While these shortages are expected to pass as covid-related bottlenecks and demand surges even-out and some new manufacturing capacity is added, it is possible that the recent Russia-Ukraine conflict complicates the picture further. And, more broadly, this points to the wider risk created by having this mix of potential points of failure within a global supply chain.

One of the drivers of specialisation in the semiconductor value chain is often the barriers to entry that can exist at each point, especially as each stage becomes increasingly defined by high levels of sophistication, skills requirements, cost and capital intensity. It is these barriers to entry that much of public policy is now focused on removing, either by providing for new R&D schemes, grant funding for manufacturing facilities or tax incentives.

Fig. 2: The illustrative journey of the smartphone



1	UK	IP created and licensed
2	US	Software provided for chip design
3	US	Fabless firm designs chip
4	Japan	Advanced manufacturing used to develop chip
5	US	Silicone wafer produced
6	Taiwan	Fab manufactures chip
7	US	Packaging
8	China	Assembly by manufacturer

1. SIA-BCG **BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf**; TSMC, **Annual report 2020.**

Fig. 3: Barriers to entry across the value chain

Value chain segment		Market Entry Barriers	Key Players
Chip Design Market Share: US 64%; Taiwan 18%; China 15%	High	The IP element requires significant R&D expenditure. For smaller start-ups, steep licensing fees for design software and IP can be a challenge.	US Taiwan Europe UK
Wafer Fabrication Market share: Japan, Taiwan, and Korea collectively 90%	Mid/ High	The barriers for entry for fabricating cutting edge <5nm chips are extremely high. Cutting edge wafer fabrication requires significant capital investment and extensive process knowledge.	Japan Taiwan South Korea
Assembly, testing and packaging market share: Taiwan 40%; China 20%	Mid	As device manufacturers and fabs are their customers, establishing these relationships can be a barrier to entering the market. As chips become more advanced companies increasingly need to be linked in to the ecosystem with material and equipment suppliers as well as access to R&D.	China Taiwan Singapore

THE UK'S PLACE IN A SHARED VALUE CHAIN

Given this mix of specialisation and high barriers to entry, it is perhaps not surprising that the UK has only a limited presence in the manufacturing steps of the semiconductor supply chain. There are just 23 fabrication plants spread across the UK and they typically tend to be producing older style (>100nm) chips. These are generally linked to specific end uses or products made in the UK. Where the UK continues to punch above its weight is in design and specifically the generation of cutting-edge semiconductor IP (shown in **Fig. 3**).

Although its global market share in the sector is relatively low, several leading producers of semiconductor IP, including Imagination Technologies, Arm and Alphawave, operate in the UK. The UK is home to two of the top design semiconductor companies and there are over 110 semiconductor design firms in the UK, making it the clear leader in Europe.[2]

2. Ilka Tuomi, JRC Scientific and Technical reports, **The Future of Semiconductor Intellectual Property Architectural Blocks in Europe.**

In addition to IP, the UK has developed more targeted specialisms in compound semiconductor manufacturing and design which reflect both the significant funding of basic research in this area and the UK's growing skills base. Some analysts estimate that the global market for compound semiconductors will reach £125bn by 2025, while others estimate it could grow to more than £300bn by 2030.[3]

Box 1: What are compound semiconductors?

Compound semiconductors combine two or more elements from the periodic table to create a wider variety of semiconductor materials, each with diverse properties. These properties mean that compound semiconductors are finding increasingly diverse applications, initially in electric vehicles and 5G.

They go through many of the same processes as silicon semiconductors and can outperform silicon in power, light and speed, but are currently more expensive and complex to manufacture.

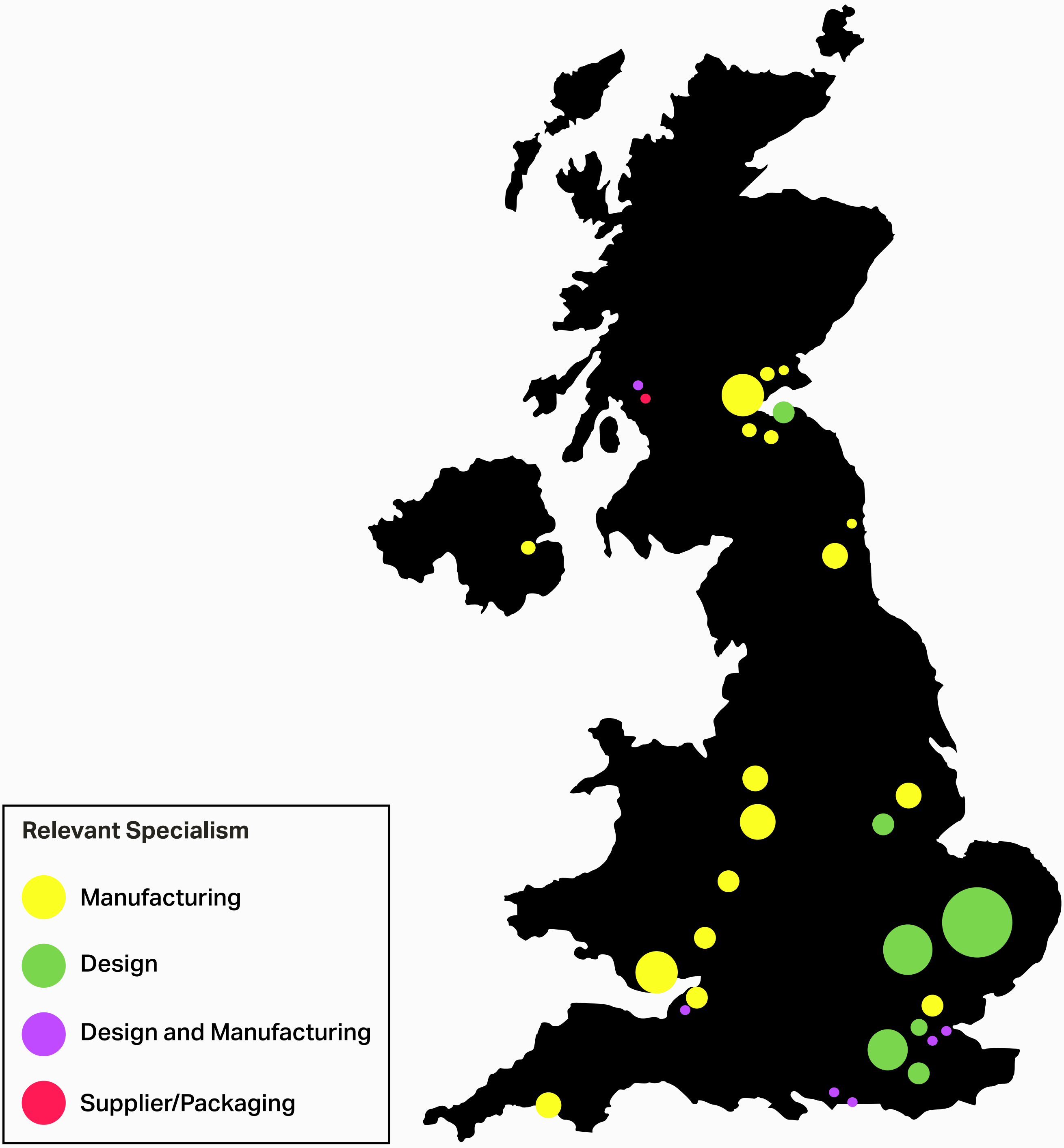
The challenge for the UK is that, even if it continues to grow its compound semiconductor industry successfully, this does not solve the present problem that policymakers are trying to grapple with - that electronics manufacturers rely on continuous improvements in the performance and cost of silicon semiconductors to drive advances in technology like smartphones and cars. There is little diversification in the manufacturing bases for these kinds of chips. In these areas, the UK still needs to rely on imports primarily from Asia.

It is this concentration of the semiconductor manufacturing base in East Asia that has led other governments to pursue onshoring strategies that seek to reduce perceived dependence on imports. But assertive attempts to onshore "missing" manufacturing in our own value chains will only reinforce the logic for other nations of focussing on their own perceived value chain gaps. Where those partners are trusted and reliable, the better compromise is a shared acceptance of a degree of interdependence based on the exercise of comparative advantages. While some states will insist on and pursue self-sufficiency,[4] some of the UK's key partners in the semiconductor value chain are much more potentially disposed to a 'shared value chain' model based on compatible strengths, free exercise of comparative advantages and acceptance of a degree of strategic interdependence.

3. Compound Semiconductor Applications Catapult (CSAC). **https://www.argusmedia.com/en/news/2120169-uk-ramps-up-investment-in-semiconductor-development.**

4. China has set out its ambition to achieve "technological self-reliance" under the 14th 5-year plan, including through massive state investment in expanded design capabilities to erode the strengths of the UK and US in these areas. Within this there is a focus on industry leading IP development.

Fig. 4: Mapping the UK's semiconductor footprint



BEYOND ONSHORING: THE SHARED VALUE CHAIN MODEL AND STRATEGIC INTERDEPENDENCE

The consensus that emerged from the interviews conducted for this report was that onshoring is neither feasible nor desirable as a UK strategy for semiconductors. The reasons for this are both economic and strategic.

First and foremost, the costs of fully onshoring semiconductor production to the UK are prohibitive. The UK imported £3.2bn of semiconductors between 2020 and 2015.[5] The cost of substituting these imports with domestic production would entail multi-billion-pound investments to be made upfront in highly advanced production facilities, infrastructure, and skills. TSMC's plans to build a semiconductor fab in Arizona are estimated to cost $12bn alone, for example. This approach is simply not viable in the UK given the capital available and economies of scale required.

Taiwan's five-decade experience of developing its capabilities in sophisticated semiconductor manufacturing serves as a reminder of the huge demands it can place on firms and government and the choices Taiwan had to make with respect to its own comparative advantages and particular focus on the foundry model **(Box 2).**

Box 2: How Taiwan became a hub for semiconductor manufacturing

Since the late 1980s and 1990s, Taiwanese firms pioneered the foundry model, specialising in manufacturing the chips designed by firms from other regions. Today, Taiwan is home to two of the five largest semiconductor foundries globally and hosts 20% of the total global capacity. Almost all of the world's capacity in the leading nodes is located in Taiwan.
To achieve this capability, the Taiwanese government has been investing in the development of its domestic semiconductor manufacturing industry since 1974 as part of a concerted industrial strategy. This has involved:

- Direct incentives in the form of tax-credits covering up to 35% of capital expenses and 13% of equipment purchases, which drove the establishment of R&D labs, industrial parks and new fab construction.
- Indirect support that has been granted to industry for several decades, including massive investment in infrastructure (power and water supply, transportation and logistics), skills, and reform of the financial sector and capital markets to facilitate access to funding.

As noted above, even if the upfront investment required was readily available, domestic UK semiconductor production would still be unlikely to be globally competitive. While the shared value chain model leverages regional specialisation, onshored domestic production would by definition work against this exercise of comparative advantage. This means fabs in the UK would have higher ongoing operating costs compared to existing ones in Taiwan, South Korea, or mainland China by virtue of losing access to lower costs of labour, electricity, and a multitude of other factors that define comparative advantages across the value chain.

5. Data extracted from **UK Trade Info** by HS code 8541. Further breakdown of data: total imports in 2020 (£482,104,185), 2019 (£565,892,029), 2018 (£530,874,613), 2017 (£677,462,833), 2016 (£1,031,557,354). Total figure £3,287,891,014.

Of course, semiconductor supply cannot be seen solely in terms of the exercise of comparative advantage. A key lesson from the ongoing global chip shortage has been that supply chains need to be resilient and robustly shielded from geopolitical instability, not just economically efficient. The case for onshoring may still have merit if it can deliver this where a shared value chain model does not. When we assess the merits of an onshoring strategy, it is therefore important to consider whether such an approach could increase the resilience of UK semiconductor supply, making it better able to withstand geopolitical tension and supply shocks, and adjust quickly to demand surges.

While onshoring could reduce the UK's dependence on imports, such a strategy would simply shift the nature of the dependence away from trading partners and onto the UK's domestic production base. This has some advantages. By depending on domestic production, the UK would not be at risk of supply disruptions stemming from trade restrictions that could block semiconductor exports to the UK. It would also reduce the risk of foreign governments imposing controls on their technologies in such a way that limited UK access to semiconductors.

However, there are considerable downsides to a strategy that promotes dependence on domestic production over international supply for a wide range of products. For one, the UK's size means it would naturally end up depending on a smaller range of domestic suppliers. This exposes us to greater risk of isolated disruptions – such as fires at fabs – causing massive disruption to UK semiconductor supply. Moreover, dependence on a smaller domestic industry means the UK would be less able to ramp up production in the case of demand surges. The result is a model of production where risk is geographically concentrated and less diversified at the firm level, and supply chains are less flexible. These factors form a material barrier to the resilience of UK semiconductor supply.

All this points to the fact that the shared value chain model is a source of strength, so long as supply chains are sufficiently diversified and flexible. This enables economies to replace imports from one country with imports from another if supply is disrupted or demand spikes. It also enables all countries in the international trading system to leverage one another's strengths in the form of their comparative advantages, leading to efficiency and greater value in the final goods that are produced.

For these reasons, the UK should chart a course that looks beyond onshoring and seeks to foster resilience in a sustainable and competitive way. The first element of this strategy should focus on building and consolidating the UK's strengths in semiconductor design, developing a comparative advantage that complements others' established strengths in manufacture and ATP. The second focuses on promoting a model of 'strategic interdependence', in which UK firms are strongly encouraged to deepen and rely on links with reliable, strategically aligned partners mutually committed to a shared value chain model. See **Box 3** for a possible framework for identifying such partners.

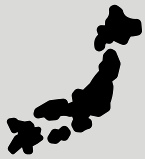
Box 3: What makes a strategic interdependence partner?

Identifying the UK's most appropriate partners for a framework of strategic interdependence in the semiconductor value chain requires a set of indicators likely to indicate their reliability as a strategic trade and production partner. Such criteria should be indicative only and may evolve over time, but could include those identified below.

Criteria	Rationale	Example partners
The partner should be politically stable and subject to minimal external or **internal threats to its stability of supply** to the UK.	Stability of supply to the UK is not only a question of the disposition of a trading partner but of the extent to which exogenous events could render it incapable of sustaining stable supply. These threats are likely to be geographical in nature, although they could in principle include scope for radical changes in domestic policy or even exposure to major environmental risks.	EU; US; Japan.
The partner should be a signatory **to the WTO ITA and ITA expansion,** ensuring a 0 tariff for semiconductors.	By becoming a signatory to the Information Technology Agreement (ITA) (1996) and ITA expansion (2015) a WTO member commits to maintaining zero tariff rates on a range of IT products that include semiconductors and multi-component semiconductors. This suggests a partner already committed to a general stance of open trade in semiconductors and high technology products in general.	Japan; South Korea; US; EU; China; India.
The existence of a **free trade agreement between the UK and a trading partner.**	For any partner not a signatory to the ITA frameworks, tariffs on semiconductors should be eliminated via a Free Trade Agreement (FTA) with the UK. As semiconductors are zero-rated in the UK most favoured nation (MFN) tariff framework (via ITA participation), the value of an FTA lies chiefly in its identification of a partner with whom the UK has chosen to deepen structural trade relations and agreed a wide range of common standards for open trade and better regulation, including IP protection.	Japan; South Korea; EU.
High levels of **FDI** in high technology manufacturing.	Material levels of fixed investment in manufacturing in the UK suggest a high level of strategic interlinkage between a partner and the UK. The existence of the new UK foreign investment scrutiny framework provides an additional layer of assurance in this respect.	Total UK inward FDI stocks: 2021: US (£434bn); Japan (£89bn); Germany (£89bn).[6]
Mutual participation in collective defence agreements, or other material **strategic cooperation commitments.**	Frameworks of this kind are a proxy for closely aligned strategic aims and imperatives and suggest a strong mutual bias to alliance and cooperation in the face of shared geopolitical or other threats.	NATO partners; AUKUS; FPDA partners; UK-Japan RAA.
A track record of **restraint in any form of export restrictions to the UK,** or the use of **national security exceptions to block UK exports.**	General restraint in the use of any form of export restrictions predicts a partner with a bias towards sustaining market-driven trade in even sensitive goods. This is especially important with respect to a partner's previous policy towards the UK. Partners with an established track record of invoking national security exceptions to block UK imports could also represent a point of weakness in any strategic interdependence framework.	Japan; South Korea.
A track record of **limited or no subjection to UK trade defence measures, especially for high technology products.**	Extensive subjection to anti-dumping or anti-subsidy measures can be a sign of a trading partner in which subsidies or other forms of state intervention can distort incentives and trade in goods, including semiconductors and where dumped imports can threaten the viability of UK producers unfairly. This should include measures imposed by the UK as part of the EU.	US; EU; Japan.
An established track **record of high-quality IP protection.**	A strong culture of IP protection predicts a jurisdiction in which the intangible assets that are key to the UK's place in semiconductor supply chains will be well protected. A score of 80 or above in the USCC GIPC global ratings for IP protection could be a proxy for this.	2021 GIPC rating (/100) Korea (83); Japan (91); Singapore (84); Germany (92) US (92).[7]

6. DIT, **Trade and Investment Core Statistics Book.**
7. US Chamber of Commerce, **Global Innovation Policy Centre.**

Example semiconductor strategic interdependence partner profile: Japan



Japan is a signatory to both ITA I and II. It operates a 0 MFN tariff on both semiconductors and multiple component semi-conductors.

UK-Japan bilateral trade is covered by the UK-Japan FTA (2021), which includes provisions on IP protection.

Japan is one of the top five foreign investors in the UK, with over £89bn in FDI stocks in 2021. More than half of this is in advanced manufacturing.

The UK and Japan are committed to closer security cooperation under the Reciprocal Access Agreement framework. Japan also acknowledges and supports the UK's regional commitments through the Five Power Arrangement.

Japan operates a conventional system of export restrictions on dual use goods, and on exports to North Korea. However, it has never imposed national security or industrial policy-related restrictions on exports to the UK in the period 1990-2022.[8]

Japan is subject to no current trade defence or other countervailing duties in the UK. The EU currently imposes anti-dumping duties on Japanese rolled steel.[9]

Japan is rated by the GIPC in the top five jurisdictions in the world for IP protection, with a rating of 91%.

THREE PILLARS FOR A UK SEMICONDUCTOR STRATEGY

PILLAR 1: SUPPORTING SEMICONDUCTOR RESEARCH AND DESIGN IN THE UK.

Given that the UK's strengths are rooted in the upstream elements of the semiconductor value chain, the UK should seek to consolidate these and its comparative advantages. Semiconductor design is reliant on specialist R&D and is difficult for countries to replicate at pace. Arm and other prominent UK players are both an example of the UK's capabilities and part of an eco-system that supports growth in this area.

Nonetheless, the UK's advantages need to be buttressed with supportive policy choices. More UK research needs to be translated into intellectual property and successfully commercialised. Our interviews reflected what can already be observed in the sector: that the key risks for the UK are falling behind others in commercialising research at pace and scale and losing high-quality UK start-ups and scale-ups with strong design capabilities through relocation.

It is clear the UK has been historically good at funding early-stage research in semiconductors through its universities and encouraging R&D tax relief for business. However, two obvious points of weakness have emerged:

1. The point at which this early-stage research is commercialised and spun out of universities, which is lost to the UK if adequate conditions for scaling up are not available.

2. The problem of applied research being done within industry but being de-prioritised because it is not yet cost effective at scale.

8. European Commission, **Trade Defence.**
9. European Commission, **Trade Defence.**

In both cases, the issue is a mix of available skills and investment. In both instances there is a role for government policy in helping identify those areas of genuinely pioneering research and then in considering how they can help the sector overcome the barriers to market. Some of this identification process is already being done through the allocation of venture capital and academic interest, although our interviewees stressed that investor understanding of the sector remains relatively low.

Both aspects of this should be directly bolstered by the UK government's commitments to increase R&D spending by 2.4% by 2030 and to make the UK a science and technology superpower. However, some elements of the government's agenda are particularly salient. The UK government's commitment to attracting the "brightest and best" in technology is particularly important for maintaining the UK's competitive advantage in semiconductor design and IP. UK semiconductor companies are competing for an increasingly mobile global pool of talent and there is international competition over engineers, so much so that a 2017 global survey of executives in the sector showed 80% of companies were concerned by shortages of engineers.[10]

Companies are also operating in an environment where many major semiconductor technology breakthroughs emerge from government- sponsored research programmes (see **Table 1**). The new Advanced Research and Innovation Agency (ARIA) legislated for earlier this year could be used to facilitate this kind of investment in the UK. While the Treasury's "Future Fund: Breakthrough" sets an important precedent for the direct funding of companies in R&D intensive industries, where there is a gap in domestic investment capital at an early stage. Helpfully both these new approaches to funding R&D give the government a potential stake in future technologies and the companies supported a clearer rationale for choosing to pursue their research and commercialisation in semiconductor design within the UK.

10. SEMI, **Deloitte-SEMI Workforce Development Survey.**

Table 1: Government-funded R&D programmes – examples	
Singapore's Agency for Science, Tech and Research (A*STAR)	This agency collaborates with leading global semiconductor companies through joint research programmes hosted in advanced R&D labs. It was founded in 1991 but has increasingly focussed on the commercialisation of research in recent years. These initiatives have since resulted in a steady stream of landmark patents, including in new semiconductor fabrication methods and advanced packaging.
U.S. Defence Advanced Research Project Agency (DARPA)	DARPA has underpinned a number of scientific and technological breakthroughs in the U.S., but in semiconductors particularly it has facilitated the pooling of resources to fund more effective research programmes. These include: 1. The Electronics Resurgence Initiative, which is ongoing and seeks to find new ways of achieving innovation outside of packing more transistors onto chips. For example, by reducing the time it takes to create a new chip design, from years to just a day by automating the process. 2. The Microelectromechanical Systems Programme, which launched in 1994 and delivered through an ever-expanding set of fabrication processes and materials, the advantages of small size, low-power, low-cost and high-functionality to integrated electromechanical systems. DARPA's success in semiconductors is and was characterised by an intense focus and finite time frame which makes it possible to attract the highest talent and inspire unusual levels of collaboration.
Interuniversity Microelectronics Centre (IMEC)	Initially funded by the Flemish government, the IMEC has become a standalone non-for-profit organisation known for its 12,000 sq m of cleanroom capacity for semiconductor processing. It is funded 20% by local government and 80% by industry and is involved in all stages in the semiconductor supply chain; but specifically focuses on supporting industry R&D, business incubation, IP licensing, prototyping and training.

What is missing from these current measures is tailoring for the semiconductor sector. These kinds of interventions have real potential for the sector, but they were not conceived of in a global context. The approach now needs to be refined with the UK's future role in the semiconductor value chain in mind.

On skills, this means that industry and government now need to play a much more proactive role in identifying gaps and creating a simple process for hiring talented engineers. This will augment, rather than detract from, existing skills programmes that are building up the UK's domestic expertise and instead compensate for the fact that UK engineers are frequently being attracted to work with competitors internationally.

It will also serve to recognise that the salary thresholds are rarely the key concern in the semiconductor industry. What is required instead is a simplified process which reflects that start-ups and scale ups in the UK are currently unable to process applications at a fast enough rate to compete with a fast-moving global market for expertise.

There are two routes that already exist that could support this; the 'scale up visa' announced by the Chancellor in the budget in autumn 2021, and the Global Talent Network announced around the same time. The scale up visa rightly focuses on limiting the administrative burden around attracting the skilled labour needed to grow business. To achieve impact this now needs to be matched by a detailed understanding on what specifically limits UK's companies' ability to compete. For example, the value chain shows certain amounts of critical mass are required to compete in the semiconductor sector. Therefore, the definition of 'scale up' that can be applied to other sectors may not be applicable to the semiconductor industry.

Some of this flexibility and tailoring can be realised through the Global Talent Network, which is intended to work with businesses and research institutions to identify UK skills needs and source talent in overseas campuses, innovation hubs and research institutions to bring to the UK.

This has the potential to offer an adapted package for the engineers that the UK semiconductor industry wants to attract, with its initial posts in the Bay Area, Boston and Bengaluru. This third location can directly respond to the fact that 20% of the world's semiconductor engineers train in India. But its intentions need to be supported by a dialogue with industry and a clear view that the semiconductor sector is a strategic priority.[11] If resource for the network is spread too broadly across tech it is unlikely to make an impact.

On R&D funding, the government also has the tools and the opportunity to be more strategic. However, as currently conceived, the impact of the Treasury's Future Fund and ARIA on the UK's semiconductor industry specifically is not likely to be discernible. These approaches should now be built upon to create a specific package for the sector.

This means the creation of a bespoke fund for semiconductors overseen by the British Patient Capital or British Business Bank (mirroring the structure of the existing Future Fund). The express purpose of this would be to acknowledge the more limited understanding of "deep tech" among investors and recognise that some may be put off by high continuing R&D costs. This could achieve a much more targeted impact without requiring the UK government to commit to anything close to the quantum that the U.S and the European Union have suggested.

This should be complemented by a new funding programme facilitated by ARIA that seeks to identify possible areas of future semiconductor development that will be world leading. This programme would challenge industry to deliver it at scale, allocating funding to a range of early-stage research and industry efforts on that basis.

This would build on the success of these types of programmes both globally and historically (see **Table 1**) and the strengths of the ARPA model in the U.S. which did not prescribe a certain solution and accepted a high level of risk when allocating capital. The flexibility of this model means that there is a potential to fund both silicon and compound solutions through a mechanism that reflects the ways in which either technology can support more cutting-edge applications.

Taken together, the below recommendations will underpin the UK's existing strengths in the semiconductor sector, enabling the UK to consolidate its role in the value chain, and leverage its competitive advantage through a series of strategic international relationships.

11. SIA-BCG analysis referred to in **BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf.**

Recommendations for supporting semiconductor research and design in the UK:

1. Ensure the UK attracts the best global talent in the sector, through the design of a new scale-up visa and the expansion of the Global Talent Network.

2. Use UK government institutions like ARIA to drive the most cutting-edge areas of design R&D for semiconductors.

3. Help fill the investment gap through the creation of a bespoke fund under the oversight of the British Business Bank or British Patient Capital that enables early-stage research to be commercialised in the UK.

PILLAR 2: PROTECTING AND PROMOTING UK SEMICONDUCTOR IP IN THE GLOBAL VALUE CHAIN.

Any strategy that prioritises the generation of semiconductor IP at home must be coupled with a strategy to protect and promote it abroad. The UK's world-leading intellectual property right (IPR) registration and enforcement system attracts innovators to the UK, but the protection of IP abroad is a necessary counterpart to that in any semiconductor strategy. This is especially important given that licensing fees for UK IP constitute a core revenue stream for the UK semiconductor industry.

Not all countries around the world, or in the wider ecosystem of semiconductor production, maintain equivalent high standards of IP protection and enforcement. In some cases, this should be seen as a material obstacle to their designation as a strategic interdependence partner in a UK semiconductor strategy. In others, it can be a spur to closer collaboration in building capacity for enforcement and evolving legal protections to reflect the best in the world.

These forms of 'IP diplomacy' make sense from a commercial perspective, but they also have a clear wider strategic rationale. By raising standards and enforcement quality for UK knowledge assets in key markets, IP diplomacy helps to create norms that will spread throughout like-minded states and widen the pool of potential partners for a UK strategic interdependence framework.

The UK is already making progress on this through the Intellectual Property Office's (IPO) internationalisation strategy. The expansion and strengthening of the IP attaché network in key embassies around the world is a welcome step. The Lambert Toolkit has been developed to help UK universities develop research partnerships in which IP is well identified and protected. Subsidised IP Audits are now available for UK businesses wishing to review their IP and IP practice.

This mix of awareness-raising at home and IP diplomacy abroad needs to be sustained and built on. As with government support for innovation, many of these initiatives could be further tailored for the specific needs of the semiconductor value chain. While the IPO understandably takes a sector-agnostic view, IP diplomacy should be targeted at states identified as strategic interdependence partners. IP attachés should be able to receive specialist training in the detail of IP issues for semiconductors, as should FTA negotiators working on IP chapters in UK FTAs.

Recommendations for protecting and promoting UK semiconductor IP:

4. Deepen engagement with strategic trading partners, exploring ways to support and expedite processes for licensing IP to partners in those jurisdictions.

5. Expand enforcement and cooperation on IPR registration and enforcement standards, especially through IP attaché networks, who should be provided with access to specialist training on semiconductor IP protection.

6. Play a greater role in educating UK industry on how to commercialise and license IP, as well as how to utilise IP rights within contractual relations.

PILLAR 3: CHAMPIONING DIVERSIFICATION THROUGH AN OPEN AND OUTWARD LOOKING TRADE POLICY.

Given that diversification generally helps to spread risk and increase resilience, UK trade policy should be geared towards supporting strategically diversified supply chains for semiconductors and their manufacturing inputs. The government has a clear role to play in facilitating this push by fostering an open trading system and deepening its trade and investment relationships with key partners. In any semiconductor strategy this should be done strategically - prioritising deeper relations with partners identified as appropriate for shared value chains and strategic interdependence.

The US, EU, Japan and South Korea are all clear candidates for deeper cooperation on semiconductors according to the criteria set out in this framework. As such, the UK should see the multi-billion-dollar investments going into semiconductor manufacturing in these markets as essentially indirect investment into its own supply, without needing to duplicate these efforts. In return for adopting this posture, the UK should expect respect for its own comparative advantages in the shared value chain and continued high protection for its knowledge assets in all of these markets. It may be advantageous to convene these shared value chain partners as a group to discuss and align on strategic objectives.

Such conversations are already taking place in forums like the EU-US Trade and Technology Council (TTC), which has a dedicated track on semiconductors under its 'Secure Supply Chains' working group. The UK has been largely absent from these strategic conversations to date, but its work towards developing its own semiconductor strategy presents an opportunity to instigate a broader strategic discussion among shared value chain partners and affirm its seat at the table. The supply chain resilience capability building initiative recently launched with Australia is a welcome step in this direction, which could be further leveraged as a plurilateral counterpoint to onshoring initiatives or exclusively bilateral forums like the TTC.

Box 4: How export controls undermine the shared value chain model for semiconductors

While export controls are - in some cases - understandably used as a national security tool or to prevent dual-use goods being used for military purposes, they must be considered within the larger context of globally interdependent supply chains. Export controls are above all else a trade-restrictive measure that imposes barriers on the shared value chain model. This is especially disruptive in a highly traded goods sector like semiconductors, which are one of the world's most widely traded products after crude oil, refined oil, and cars.

Export controls have had a material impact on semiconductor supply chains in the past. For example: In 2019, Japan imposed export controls on semiconductor materials to Korea, impacting approximately $7 billion in semiconductor exports per month.

The impact of such measures has not only been to disrupt supply in the short term, but also to encourage tit-for-tat behaviour that can lead to a cycle of negative reciprocity in the longer term. This undermines trust between trading partners and works against the logic of maintaining open and diversified supply chains.

Finally, export controls can at times cast too wide a net that unintentionally incentivises R&D to move offshore and encourages trading partners to develop their own indigenous capabilities. This has arguably been the most impactful and enduring consequence of the US imposition of export controls on Chinese technology, which had spurred China's ambition to achieve "technological self-reliance" under the 14th five-year plan.

Among this group of shared value chain partners, the UK should pioneer a general understanding that participants will:

1. Maintain zero-tariff trade on an MFN basis for all semiconductors and their inputs;

2. Avoid forms of industrial policy or commercial practice that could trigger trade disputes or trade defence measures in these areas; and

3. Refrain from any unjustified use of export controls for semiconductors or their inputs.

Given the materiality of the export controls, the UK should seek to work with its shared value chain partners to develop a common framework for the use of export controls that is proportionate, targeted, and supported by a clear rationale. This should complement and build on the Wassenaar Arrangement, focusing on common protocols that increase the transparency behind decision-making on export controls. Indeed, a lack of transparency only serves to undermine the ability to work with trading partners and prevents buy-in from industry stakeholders when designing supply chain strategies for critical technologies.

Recommendations for championing diversification:

7. Support the diversification of the UK's semiconductors chain through a body modelled on the TTC that convenes a group of strategically interdependent shared value chain partners on semiconductor trade and reinforces their cooperation.

8. Pioneer a common approach to export controls that recognises controls must be targeted, proportionate and justifiable.

CONCLUSION AND SUMMARY OF KEY RECOMMENDATIONS

The events of 2020-2022 have rightly compelled the UK to consider its strategic approach to ensuring that its domestic industry maintains a reliable supply of semiconductors. As a hugely valuable and ubiquitous component in advanced manufacturing and modern technologies, this question should also be linked to the question of the UK's own place in any global value chain for their production.

This report has addressed both questions. Its argument is that the strategic approach of the UK in semiconductors should not be to secure supply through domestic onshoring or any attempt at self-sufficiency. The costs of establishing this capability in an economy the size of the UK would be prohibitive and only a shift reliance of a landscape of global partners to reliance on a small number of globally uncompetitive domestic producers.

Rather, the UK should seek to maximise the benefits of its own existing strengths in the semiconductor value chain which lie firmly in the creation of the critical IP that underpins it. Buttressed by formidable strengths in basic research and a world-class environment for IP protection, this is the UK's clear comparative advantage in a shared value chain for semiconductors that spreads design, manufacturing and assembly across multiple markets internationally, each recognising the utility of mutual dependence that reflects their different comparative advantages.

But such an approach must involve very careful judgements on where the UK allows this strategic interdependence to develop. As part of a semiconductor strategy, the UK should develop a set of criteria for identifying trusted, reliable, like-minded partners in a shared value chain. These criteria should include high levels of strategic alignment with the UK, common approaches to trade policy and IP protection. This report has proposed what such a set of criteria might look like:

SUMMARY OF KEY RECOMMENDATIONS

AS PART OF THIS WIDER STRATEGY, THE UK SHOULD CONSOLIDATE ITS STATUS AS ONE OF THE BEST PLACES IN THE WORLD TO PRODUCE SEMICONDUCTOR IP BY:

1. Ensuring the UK attracts the best global talent in the sector, through the design of a new scale-up visa and the expansion of the Global Talent Network.

2. Using UK government institutions like ARIA to drive the most cutting-edge areas of design R&D for semiconductors.

3. Helping fill the investment gap through the creation of a bespoke fund under the oversight of the British Business Bank or British Patient Capital that enables early-stage research to be commercialised in the UK.

IT SHOULD STRENGTHEN THE PROTECTION OF UK IP ABROAD BY:

4. Deepening engagement with strategic trading partners, exploring ways to support and expedite processes for licensing IP to partners in those jurisdictions.

5. Expanding enforcement and cooperation on IPR registration and enforcement standards, especially through IP attaché networks, who should be provided with access to specialist training on semiconductor IP protection.

6. Playing a greater role in educating UK industry on how to commercialise and license IP, as well as how to utilise IP rights within contractual relations.

IT SHOULD DEFINE AND CONVENE A GROUP OF TRUSTED STRATEGIC INTERDEPENDENCE PARTNERS THAT ARE PART OF A SHARED VALUE CHAIN FOR SEMICONDUCTORS. THIS SHOULD INCLUDE:

7. Supporting the diversification of the UK's semiconductors chain through a body modelled on the TTC that convenes a small group of strategically interdependent partners on semiconductor trade and reinforces their cooperation.

8. Pioneering a common approach to export controls that recognises controls must be targeted, proportionate and justifiable.

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