

Semiconductors

Technology's Not-So-Fat Conductor

WEALTH MANAGEMENT RESEARCH

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Whether you know it or not semiconductors likely play a massive role in your life, but the majority of us are blissfully unaware of what a semiconductor is and the gigantic industry that surrounds them. With the continued growth in demand for semiconductors we are positive about the potential this industry has, however, we firmly believe that investors should have a sound understanding of the industries and businesses they choose to invest in. In the case of the semiconductor industry, with complex products and varying business models, this can be difficult. In this report we offer an overview of the semiconductor industry to provide investors with a foundational understanding for investing in this industry. The key questions we address are:

- What are semiconductor chips?
- How are semiconductor chips produced?
- What are the industry dynamics?
- What are the drivers of future growth?
- What are our preferred exposures?

Keeping it brief

As the world increasingly shifts towards digital dependence, through drivers such as 5G (the next mobile technology) and Artificial Intelligence adoption, the use of semiconductors is only set to increase. Semiconductor fabrication takes place at a microscopic level; with high demands on innovation and capital equipment expenditure. Similar to the products, the industry itself is also highly complex. Businesses operate under different business models, some opt for vertical integration while others choose to specialise, and supply chains stretch the entire globe. Considering the long-term growth drivers and looking through any near-term inventory build up we see a positive future for this industry. Our preferred exposures within the semiconductor supply chain are Intel (INTC.O), NVIDIA (NVDA.O), Qualcomm (QCOM.O) and Taiwan Semiconductor Manufacturing Co (TSM.N, 2330.TW).

Intel (INTC.O)

INTC is the world's largest and highest valued semiconductor chip manufacturer based on revenue and the world's #1 microprocessor supplier for desktop PCs, notebook PCs, and servers – with approximately 92% market share. Despite reported delays in their advanced manufacturing technology, we believe Intel (INTC.O) is well positioned to recover and improve the execution of their manufacturing operations.

NVIDIA (NVDA.O)

NVDA is a market leader in the development of graphics processing units (GPUs). This core strength positions NVDA well to transition from its past focus on PC components to providing diverse gaming, data centre, and automotive software platforms.

Qualcomm (QCOM.O)

QCOM's business strategy has been to invest in fundamental technologies that enable industries and then scale it worldwide. QCOM invested heavily in the 5G transition and now stands to be the leading global supplier of 5G modems and antennas, making it one of the biggest beneficiaries of the rollout of 5G.

Taiwan Semiconductor Manufacturing Co (TSM.N, 2330.TW)

TSMC supports a thriving ecosystem of global customers and partners with the industry's leading process technologies, while having a portfolio of design solutions to enable innovation in the global semiconductor industry. TSMC has a global foundry market share of 56% and growing. TSMC is not only the biggest, but also the best.

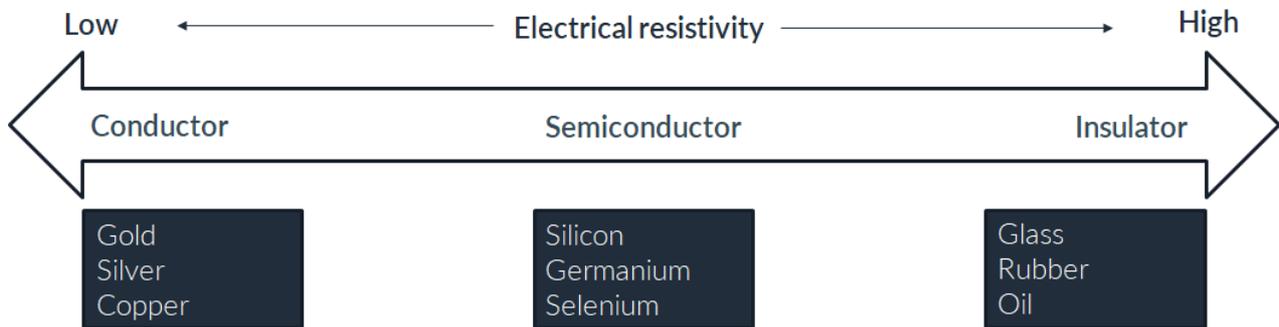
What are semiconductor chips?

Before diving into specific companies and the industry dynamics it's important to understand what we are talking about. In short, semiconductor chips are the enablers of modern electronics. Sometimes referred to as integrated circuits (ICs) or microprocessors they are ubiquitous in modern society with more than 100 billion in daily use around the world; you can find them in your car, computer, phone, and wearables – just to name a few applications.

Its reference to the material

Semiconductor chips get their name from the material they are printed on, semiconductors. The term semiconductor refers to the electrical resistivity of a material. Low electrical resistivity in conductors, like gold, allows electrical currents to flow easily through the material, whereas insulators are the opposite, inhibiting electrical flow. Sitting in the middle of these are the semiconductors that (importantly) exhibit characteristics of both. Semiconductors are useful because we are able to make alterations to the material (known in the industry as doping) to control the flow of electricity. The semiconducting material of choice is silicon (hence Silicon Valley, where many technology firms are based). Given our insatiable appetite for semiconductors it's lucky that silicon is one of the most abundant materials in the world.

Figure 1. It's all about electrical resistivity



Source: Forsyth Barr analysis

How you harness its properties is key

In their raw form semiconductors are not all that useful, but what makes a semiconductor special is the ability to create built-in transistors, thus creating semiconductor chips. You can think of a transistor as a microscopic switch which exists in two binary states, 1 and 0 (on or off), and can move between these states billions of times per second. Unlike ordinary switches, these transistors have no moving parts, instead they are built into the semiconducting material by altering the properties of small segments. By connecting all these transistors together we can create an integrated circuit (IC), where the transistors work in concert to help computers or devices complete calculations, providing the foundation for electronics.

Why transistors?

Computers need millions or even billions of transistors to complete tasks. One semiconductor chip can have millions of transistors continually switching states, helping complete complex calculations. For context, the 7nm semiconductor chip manufactured by TSMC, has approximately 100 million transistors per square mm, each one being 100,000 times smaller than the width of single human hair. With many transistors, a computer can make many simple decisions very quickly, and thus perform complex calculations very quickly.

Analog vs digital semiconductor chips

Broadly, the semiconductor industry is divided into analog and digital semiconductor products. Analog semiconductor chips measure and regulate real world functions, such as: speed, electrical current, temperature and sound. Analog chips have mostly been replaced by their digital counterparts but are still required for wideband signals and are still used in sensors. Digital semiconductor chips process binary information, used by computers. The two main digital semiconductor chips produced globally are memory and processor/logic chips. Logic chips, also considered the brains of computing, provide the basis for computational power. Memory chips, evident in the name, are responsible for electronically storing data in the form of bits. Currently, the US has the largest global production of logic chips, ~60% of market share, while Korea leads global production of memory chips, with ~65% market share.

Mixed-signal devices incorporate both analog and digital functions onto a single chip. The analog and mixed-signal industry is typically characterised by longer product life cycles than the digital industry and in addition has lower capital investment requirements. This is due to the facilities being less dependent on state-of-the-art production equipment needed to process leading-edge technologies.

Figure 2. Examples of semiconductor chips

Chip type	Application	Description
Digital	Processor/ Logic	CPU Central Processing Unit: primary component of a computer that processes instructions. These run the operating systems and applications for our electronic devices
		GPU Graphics Processing Unit: specialised electronic circuit used to render images, however, are now becoming widely adopted in Artificial Intelligence applications
	Memory	DRAM Dynamic Random Access Memory: known as volatile memory, only stores memory when it is connected to power. Commonly used in mobile devices and data servers
		NAND Stores memory even without power. Commonly used in memory cards and solid state drives (SSD)
Other	SoC System on a Chip: a combination of logic and memory architectures consolidated on a single chip	
Analog	Sensor	Temperature Temperature sensors produces a voltage proportional to the temperature for interpretation, if necessary this can be converted to feed into a digital circuit
		Sound Sound sensors translate the amplitude of the acoustic volume of the sound into an electrical voltage for sensing sound level

Source: Forsyth Barr analysis

While both the list of semiconductor applications and companies is long, we have selected a few prominent companies to highlight the different exposure characteristics they possess.

Figure 3. Key exposures by company

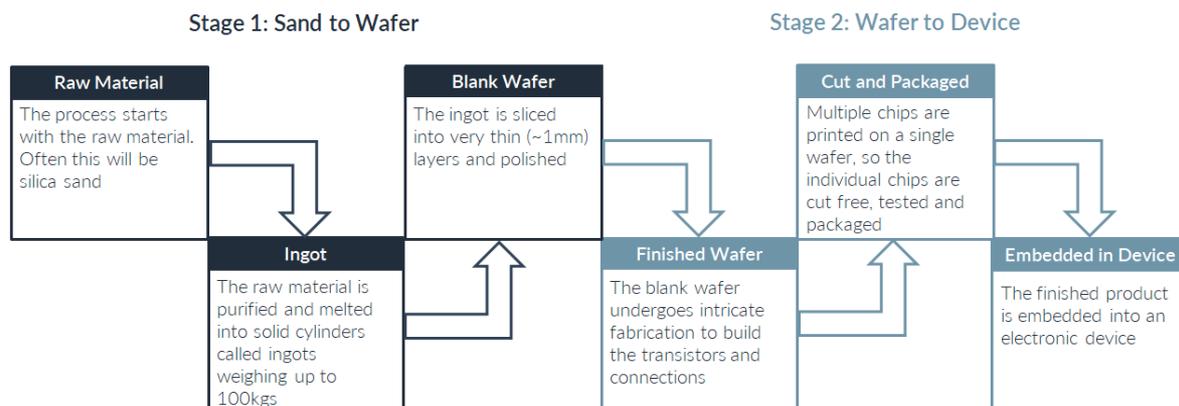
Companies	Ticker	Digital					Analog
		SoC	CPU	GPU	DRAM	NAND	
Intel	INTC.O	X	X	X	X		
Samsung Electronics	005930.KS				X	X	
Micron Technology	MU.O				X	X	
Taiwan Semiconductor Manufacturing Co (TSMC)	2330.TW	X	X	X	X	X	X
NVIDIA	NVDA.O	X		X			
Qualcomm	QCOM.O	X	X	X			
Advanced Micro Devices	AMD.O	X	X	X			
Broadcom	AVGO.O	X	X	X			X
Xilinx	XLNX.O	X					
Texas Instruments	TXN.O						X

Source: Forsyth Barr analysis

How are semiconductor chips produced?

The process of designing and fabricating chips from semiconductors is extremely intricate and complex. Part of the complexity comes from the microscopic scale of construction. Leading-edge technology can produce transistors around 5–7nm (1 nanometre = 0.000000001 metres).

Figure 4. Manufacturing process



Source: SIA, Forsyth Barr analysis

Stage 1 – Sand to Wafer

This part of the process is fairly basic, silica sand is melted down and purified to produce pure silicon ingots. It is here that doping can occur. Doping involves adding a non-silicon element to alter the conductivity of the material, depending on its final use. These ingots are shaped into perfect cylinders and are usually around 100kgs in weight. The cylinders of silicon are then finely sliced into 1mm thick wafers and polished.

Stage 2 – Wafer to Device

There are three main processes to fabricating chips from wafers; deposition, lithography, and etch and clean. All three processes also require process control. Here's how it works:

- **Deposition:** Layers of conducting or insulating materials are sprayed or deposited onto a silicon wafer
- **Lithography:** Inside a Step-and-Scan system, special lights that are similar to lasers and x-rays are shined through a photomask to transfer the chip design onto the wafer
- **Etch and Clean:** Some of the material on the wafer is etched and cleaned off to deliver the desired designs and patterns

These processes are repeated between 30–100 times to create chips on the wafer. A 300mm diameter wafer can be used to produce around 70,000 chips. Process control equipment is used throughout the process for inspection and measurement to aid in removing defects and increasing yields.

As chip fabrication and design improves it unlocks further possibilities

The race is always on to produce semiconductor chips with faster processing speeds and lower power consumption. This is achieved by packing more transistors into a given space and chip design.

More transistors allow a single chip to perform more calculations, smaller transistors also switch between states faster and require less power to do so. The rate of improvement in the number of transistors on a circuit is said to follow Moore's Law. Moore's Law is an observation made by Intel's Co-founder Gordon Moore in 1965, which states that the number of transistors that can fit into a circuit doubles roughly every 2 years. When Moore made this statement, the intention was not to create a law, but instead was an insight into current trends – which transformed into a prediction, before finally being established as the golden rule. While Moore's Law remained true for many years it cannot continue forever. There is rising belief among experts that computers will reach the physical limits of Moore's Law in the 2020s, due to the high transistor count causing high temperatures. As we reach the limits of Moore's law, leading-edge chips are relying on chip design to improve power. Focusing on the transistor connections to improve performance. These leading-edge chips are critically important in fields such as AI where computing power is paramount. However, new technology comes with some trade-offs, such as reliability and price, because of this not all devices require the latest technology. In other words, new technology doesn't completely cannibalise the old.

Industry dynamics

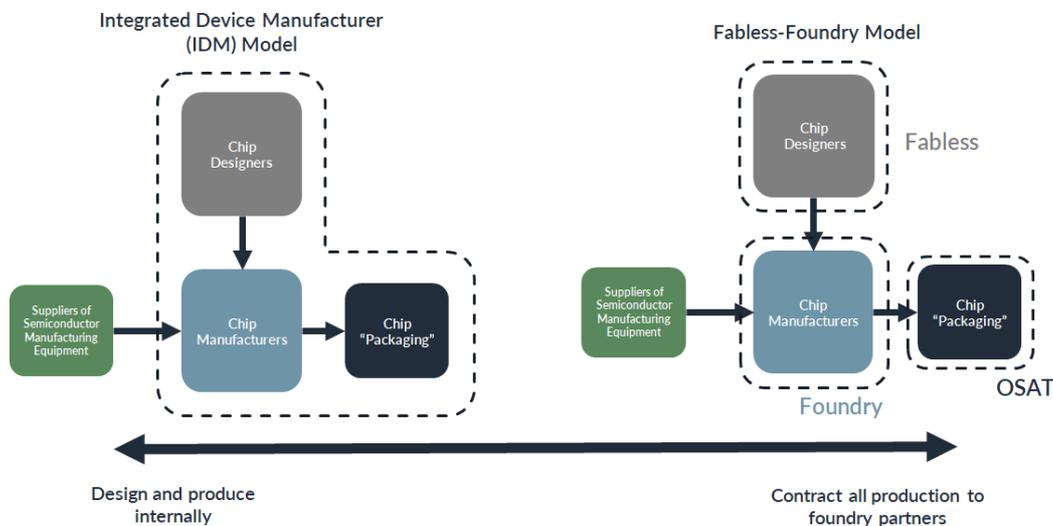
The semiconductor industry is a truly global and complex beast – it is estimated that components can travel 40,000kms before finding their way into the final product. Understanding some of the key aspects of this industry is critical for selecting investments. Our key considerations within the semiconductor industry are:

- The ongoing shift in business models
- The highly cyclical nature of the industry
- Drivers for growth

Shifting business model

Semiconductor companies have been shifting from the traditional Integrated Device Manufacturer (IDM) model towards what is known as a “Fabless-Foundry” model. In the Fabless-Foundry model companies who design chips outsource the fabrication (or fab, hence fab-“less”) to foundries, and the testing and packaging to outsourced assembly and test (OSAT) companies. This shift represents the disaggregation of the semiconductor chip value chain, on the premise that specialisation in segments of the value chain will yield better results overall.

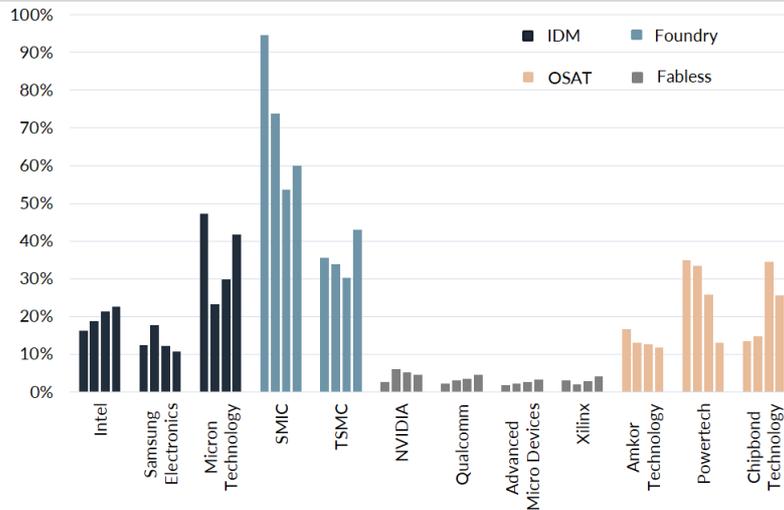
Figure 5. Two main business models



Source: Forsyth Barr analysis

One of the common mistakes made by investors is directly comparing companies in the industry, despite their different models. Perhaps the most distinguishing feature are the capital requirements faced by firms involved in chip fabrication (Figure 6). To add further complexity some companies adopt a hybrid model, choosing to outsource only a portion of fabrication. Directly comparing these companies can be likened to comparing General Motors, Uber and Hertz on the basis they all involve cars. While they are broadly involved in the same industry, they each face unique challenges, we outline some of these below.

Figure 6. Capex/Revenue – last four FYs



Source: Thompson Reuters, Forsyth Barr analysis

Equipment Supplier

While these companies are not included in either business model they provide the equipment necessary for chip fabrication. Suppliers are broken into two categories; Front-end or wafer fab equipment (WFE) and back-end or test and packaging suppliers. Around 85% of the capital expenditures made by chip manufactures is for WFE. Some companies involved in equipment supply are:

- Applied Materials (AMAT.O): Has the leading market share (57%) in **deposition** equipment
- ASML (ASML.AS): Has the dominate market share (~75%) in **lithography** equipment
- Lam Research (LRCX.O): Has the leading share (~57%) in **etch and clean** equipment
- KLA-Tencor (KLAC.O): Has the leading market share (~55%) in **process control** equipment

Integrated Device Manufacturer (IDM)

IDMs are the do-it-all of the industry and the traditional business model for semiconductor chip production. In order to remain competitive these companies are required to remain at the leading-edge of chip manufacturing while simultaneously investing in the innovation of chip architecture. Capital allocation is key to avoid falling behind in either of these key areas. With the rise of the fabless model many IDMs have joined the movement splitting themselves into two pieces – a fabless design firm and a foundry – and gone their separate ways. AMD is an example of this, now a fabless firm they spun-off their foundries as GlobalFoundries in 2009. Whilst the number of IDMs have diminished in recent years, the question still remains as to whether the two business models can co-exist in the long term. Three key IDMs are:

- Intel (INTC.O): The world's #1 microprocessor supplier for desktop PCs, notebook PCs, and servers – with approximately 92% market share
- Micron Technologies (MU.O): An expert in memory semiconductors, Micron's largest customers include PC/data center original equipment manufacturers, handset makers and supply partners
- Samsung Electronics (005930.KR): Samsung is a world leader in memory semiconductors, while Samsung provides some foundry services, they are also vertically integrated and derive revenue from outside the semiconductor industry

Outsourced Assembly and Test (OSAT)

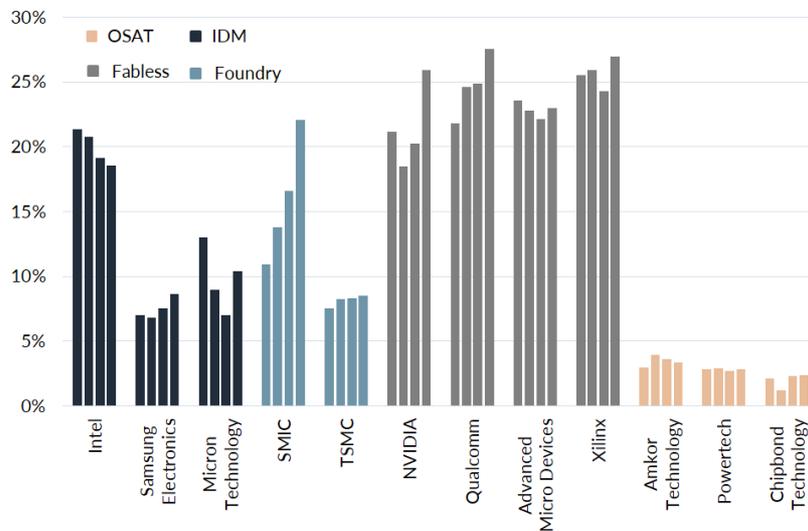
The OSAT market is the smallest within the semiconductor industry. It is characterised by very low barriers to entry, leading to high competition and lower profitability. For these reasons we view this as the least attractive segment in this industry.

Fabless

Foundries remove what was once the biggest barrier to entry in the semiconductor market – capital requirements. Leaving fabless companies to focus on the architecture of semiconductor chips, a function requiring substantial innovation and R&D costs (Figure 7). Fabless companies will often specialise in a type of semiconductor chip (e.g. memory or GPU), working to secure patents in their area of expertise. Key considerations for investing in fabless companies are the future demand for the product the company has expertise in (will future technologies require more GPUs, CPUs, or memory chips) and the level of patent protection the company has. Leading fabless companies are:

- Advanced Micro Devices (AMD.O): The #2 supplier of microprocessors for desktop PCs, notebook PCs and servers. AMD competes with Intel in the microprocessor segment and NVIDIA in the graphics segment
- NVIDIA (NVDA.O): Operates predominantly in the GPU segment used in gaming, data centres and automotive end markets
- Qualcomm (QCOM.O): Products are primarily used in handsets with Apple and Samsung contributing to c.39% of revenue
- Xilinx (XLNX.O): The #1 supplier of programmable logic devices with 50% market share and a wide range of uses

Figure 7. R&D/Revenue - last four FYs



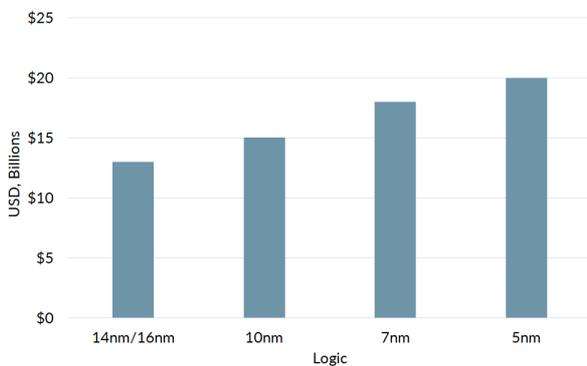
Source: Thompson Reuters, Forsyth Barr analysis

Foundry

Semiconductor foundries are contract manufacturers that provide front-end wafer processing services for their customers and benefit greatly from economies of scale. Foundries compete to have leading-edge technology, which is capable of producing more powerful semiconductor chips. Every new advancement (according to Moore's Law at least every 2 years) requires new equipment, which is only becoming more expensive (Figure 8). For this reason the average capex-to-sales ratio for foundries is c.40%. The capital-intensive nature of fabrication and ever-increasing technological requirements makes it increasingly difficult for companies who fall behind to catch up. Over the last 20 years the number of leading-edge chip fabricators has decreased from 29 to 3 (Figure 9). TSMC is the only foundry, with IDMs Intel and Samsung also considered to be at the leading edge, although TSMC is beginning to extend its advantage. As previously mentioned, leading-edge technology is not the entire market and other foundries are trying to catch up to TSMC. Some key remaining foundries are:

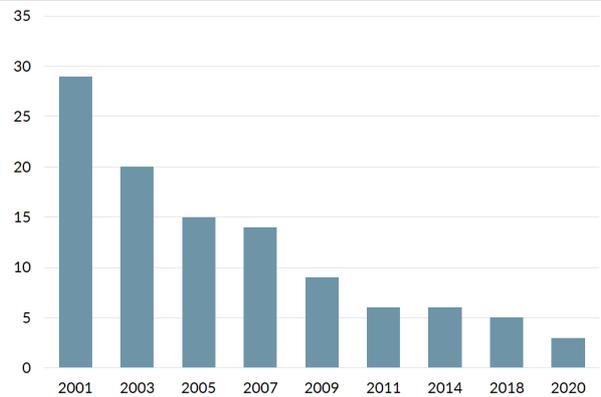
- Taiwan Semiconductor Manufacturing Co (TSMC – TSM.N, 2330.TW): By far the largest foundry holding c.56% market share and at the forefront of leading-edge technology with 5nm node fabrication technology
- United Microelectronics Corp (UMC – 2303.TW): Another foundry based in Taiwan (c.7% market share), however, with 14nm node technology UMC is not as advanced as TSMC
- Semiconductor Manufacturing International Co (SMIC – 0981.HK): Part of China's attempt to build self-sufficiency in the semiconductor space. SMIC currently has 14nm node technology, but is investing heavily to increase its technological capabilities

Figure 8. WFE cost (Greenfield, 100k wafer starts a month)



Source: SIA, Forsyth Barr analysis

Figure 9. Firms manufacturing leading-edge technology



Source: SIA, Forsyth Barr analysis

The fabless model may not end up quite as fabulous as thought

While the removal of large capital requirements currently bodes well for the fabless designers, the existence of foundries may allow the end customers to by-pass them entirely.

With the ever-increasing demands of technology comes the desire for more application specific semiconductor chips. The current mass-produced chips are designed to satisfy the needs of many different customers, creating the opportunity for companies to increase performance by designing semiconductor chips specific to the needs of their devices. When executed correctly the difference is analogous to a decathlete competing in a 100m race, while their effort would no doubt be commendable, they would not compete with those who trained solely for the 100m race.

We have been seeing examples of this for a number of years, in fact Apple has been designing the System on a Chip (SoC) used in iPads and iPhones since their inception. Apple achieves this by licensing semiconductor architecture from UK-based Arm (NVIDIA has just announced they will acquire Arm from Softbank) and then customises the design to suit their needs. Two developments in the past year further develop this narrative:

- 1) Apple acquired the majority of Intel's smartphone modem business. Providing a foundation to develop their own 5G modems for smartphones. Apple is currently reliant on Qualcomm for 5G modems. Despite recently signing a multi-year agreement the companies relationship has not been all smooth sailing, with recent legal disputes. As such, it would not seem unreasonable that Apple would seek to reduce their reliance on Qualcomm in the years to come.

- 2) Apple announced they would no longer use Intel for the processor chips in their Mac computers. Instead Apple would use "Apple Silicon" developed in-house, again using ARM-based architecture. This move provides Apple with the benefits of customised processor design and access to the more advanced manufacturing facilities of TSMC.

Neither of these are expected to dramatically impact Qualcomm or Intel immediately, however, the medium- to long-term impacts could be material. Further still, Apple is by no means the only major corporation on this pathway. Other examples include Tesla designing its own AI chips and Amazon designing an Arm-based chip for use in its data centers. If these ventures prove successful we expect to see increasing pressure on the fabless designers.

Of course there are many other companies reliant on semiconductor technology without 1) the means of designing their own semiconductors or, 2) the need for customised designs and therefore will require the products of fabless designers and IDMs. In our view successful fabless companies and IDMs need to offer the flexibility that ARM does, truly market leading designs, or both.

A quick note on China

China is the biggest market for semiconductor consumption, but accounts for only 5% of global sales. China's external dependence for semiconductors has, for years, spurred the Chinese Government's strategic planning and investment in their domestic semiconductor industry. To date these attempts have been unsuccessful. That is not to say it is impossible for latecomers to succeed. Japan, South Korea and Taiwan were all able to find success in this industry despite being latecomers. Recent escalation in US-China trade tensions only further incentivises China to build semiconductor self-sufficiency.

While we do not know how these trade tensions will conclude, disruptions to the free flow of resources among semiconductor companies and end users is a risk that warrants investors attention.

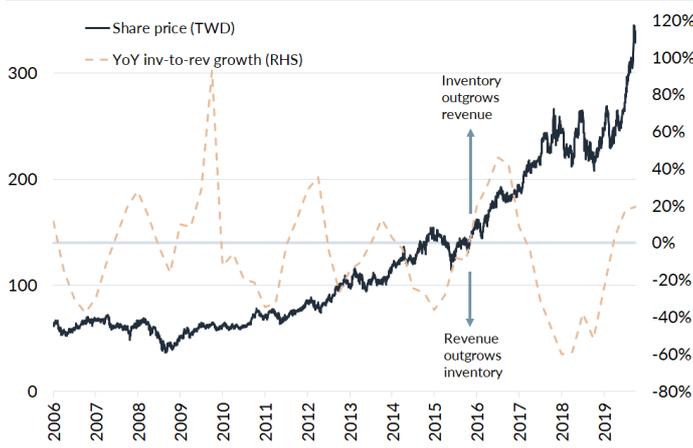
Industry cycles

The semiconductor industry is notoriously cyclical, in fact it's not uncommon to see share prices drop by 50% in a down cycle. We view inventory cycles and end-user demand shocks as two key drivers of these cycles. Before making an investment, investors must understand where we currently are in the cycle and those taking a long-term view must be prepared to ride out the ups and downs.

Inventory cycles (over/under production)

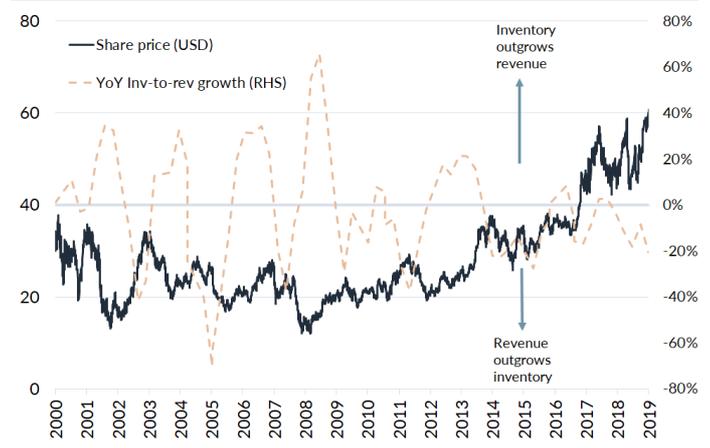
The industry is prone to over/underestimating the required production levels. When times are good companies are overly optimistic, increasing production to unsustainable levels. At the heightened levels of production inventories begin to build leading to an oversupply and forcing manufacturers to cut prices and production. At the opposite end of the cycle companies tend to be overly pessimistic, under producing as demand increases. We can see this illustrated in Intel and Taiwan Semiconductor Manufacturing Co's (TSMC) share price. On the premise that inventory is purchased to cater for the next period's demand, we analyse last quarters inventory growth net of current quarter revenue growth. We observe that periods of sustained excess inventory growth results in share price under-performance.

Figure 10. TSMC



Source: Thompson Reuters, Forsyth Barr analysis

Figure 11. Intel



Source: Thompson Reuters, Forsyth Barr analysis

End-user demand shocks

Complementary to inventory cycles are overall demand shocks – where events (new tech or recessions) lead to a rapid change in demand. Previously the demand for semiconductor chips was predominantly driven by personal computer demand, however, an increasing number of products are becoming reliant on semiconductors chips. A growing number of end-use products should have a stabilising effect on demand, reducing the impact demand shocks have on the cycle.

Drivers of growth

The world is now in the early-stages of substantial technology-driven change, welcoming in the era of digital transformation and AI. Breakthrough applications in the areas of virtual/augmented-reality, the Internet-of-Things (IoT), 5G connectivity, Industry 4.0, quantum computing, autonomous vehicles and smart cities are slowly becoming commercially viable. The semiconductor industry has always been at the heart of revolutionary step-changes in information and communication technology (ICT), and these breakthroughs are positive indicators for economic growth. In our view, four of the key areas of innovation set to benefit the semiconductor industry are:

5G

- Brings the promise of faster speeds, lower latency and the ability to connect to more devices.
- Semiconductors enable the radios that transmit signals, devices that connect to the network, and the backbone networks that carry the data.

Artificial Intelligence (AI) and Internet of Things (IoT)

- For AI the cloud provides the biggest market potential. Companies no longer need to own the physical hardware but instead can access computing power through the cloud; increasing efficiency, reducing operational cost, and improving infrastructure management.
- GPUs have become the mainstream choice for AI chips (over 30% market share). They allow for parallel computing, where complicated tasks can be separated into a number of components and solved simultaneously.

Electric vehicles and autonomous driving

- Autonomous driving: requires sensing, modelling, AI enabled-cameras and decision making. All of these steps require AI chips.
- While EVs and autonomous driving will leverage advancements in AI, 5G and IoT, they also have their own unique characteristic. The automotive industry doesn't necessarily require the leading-edge tech; size is less of a concern and some vehicle sensors are still manufactured at 150nm. The failure requirements are also more stringent in automotives, which the leading-edge tech doesn't deliver on.

Wearables

- Wearables, such as earwear/hearables, watches, wristbands and others, are well on the way to becoming a staple for consumers. The wearables market is estimated to ship 330 million units in 2020, increasing to around 550 million units in 2024, giving a 4-year CAGR of 9.4% (Citi, Global Technology Supply Chain Handbook, 2020)
- Small-sized semiconductors are well suited for wearables and IoT devices due to the low power consumption, small footprint, analog data acquisition and integrated display capabilities

Forming a long-term view – our preferred exposures

Considering the long-term growth drivers and looking through any near-term inventory build up we see a positive future for this industry. Within the Fabless companies we favour NVIDIA (NVDA.O), for their exposure to gaming, data centre and automotive markets, and Qualcomm (QCOM.O), for their exposure to the current wave of 5G adoption. For foundries we favour TSMC (TSM.N, 2330.TW) as their technology leadership places them well to capture market share in the years ahead. Despite reported delays in their advanced manufacturing technology, we believe Intel (INTC.O) is well positioned to recover and improve the execution of their manufacturing operations.

Intel (INTC.O)

Intel Corporation (INTC) is an American multinational corporation and technology company headquartered in Santa Clara, California, in Silicon Valley. It is the world's largest and highest valued semiconductor chip manufacturer based on revenue, and is the inventor of the x86 series of microprocessors, the processors found in most personal computers. INTC's business strategy has five core pillars: Make the Worlds best semiconductor – Moore's Law, predicted by co-founder Gordon Moore more than 50 years ago, continues to be a strategic priority and differentiator. Lead technology inflections drivers of change today are AI, the transformation of networks spearheaded by the transition to 5G. Be the leading end-to-end platform provider deliver solutions that enable customers to move faster, store more, and process everything. Focus on operational excellence and efficiency includes the elimination of lower growth investments and activities. Hire, develop, and retain the best, most diverse and inclusive talent.

NVIDIA (NVDA.O)

NVIDIA (NVDA) is a market leader in the development of graphics processing units (GPUs), which crunch a lot of data while consuming minimal power. This core strength positions NVDA well to transition from its past focus on PC components to providing diverse gaming, data centre, and automotive software platforms. NVDA has established a significant head-start in the race to capture market share as new technologies revolutionise a number of end markets, such as Level 5 autonomous vehicles, virtual reality, gaming-as-a-service, blockchain, and smart cities. Interestingly, NVDA derives 87% of its revenue from foreign countries, namely Taiwan at 29%. NVDA primarily operates in two segments; Graphic Processing Unit (GPU) is the main business segment for the company, generating 87% of total revenue. Tegra Processors are mainly Systems on a chip (SoCs) used in tablets, smartphones and gaming devices to integrate all the components of an electronic system. Tegra Processor sales generate 13% of the company's revenue.

Qualcomm (QCOM.O)

Qualcomm (QCOM) is an American communications company that started in the late 1980s. Success came fast to QCOM, with large demand in the '90s for satellite communication for trucking companies. QCOM's business strategy has been to invest in fundamental technologies that enable industries and then scale it worldwide. This strategy is currently being applied to 5G; QCOM invested heavily in the 5G transition and now stands to be the leading global supplier of 5G modems and antennas, making it one of the biggest beneficiaries of the 5G rollout. QCOM is a fabless semiconductor company, meaning it designs all its semiconductors, then contracts a foundry (TSMC) to make the semiconductor chips using the design provided. These chips are what powers QCOM's mobile processors, cellular modems, Wi-Fi modems and Bluetooth connectivity. Of QCOM's revenue, 25% comes from the licensing business which collects royalties for the use of QCOM's intellectual property.

Taiwan Semiconductor Manufacturing Company (TSM.N, 2330.TW)

TSMC pioneered the pure-play foundry business model when it was established in 1987, and has been the world's largest dedicated semiconductor foundry ever since. The company supports a thriving ecosystem of global customers and partners with the industry's leading process technologies and a portfolio of design solutions to enable innovation in the global semiconductor industry. TSMC has a global foundry market share of 56% and growing. TSMC is not only the biggest, but also the best. When it comes to semiconductors, size matters – the smaller the better. TSMC was the first company to produce the 16nm, 10nm, 7nm and 5nm semiconductors (each smaller than the last) and is on track to pioneer the 3nm, as well as being the first company to commercialise Extreme Ultraviolet (EU) lithography in high volumes. Foundries such as TSMC are set to gain the most margin from the transition to 5G. TSMC's major customers are Qualcomm, Apple, NVIDIA, AMD, STMicroelectronics, Google and possibly soon Intel.

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