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Why High-Tech Commoditization Is Accelerating

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BY WILLY SHIH

THE LEADING QUESTION
How can technology companies protect themselves from commoditization?

FINDINGS

- **Advanced production tools commoditize the manufacture of many hardware products, making differentiation more difficult.**
- **Modern computerized design and simulation tools reduce the value of experience.**
- **As product designers use increasingly sophisticated building blocks, complementary assets become more critical.**

FOR TECH COMPANIES that rely on sophisticated engineering, staying ahead of international competition seems to get harder every day. It used to be an article of faith that technology-intensive product manufacturers, automakers, or white goods makers could capitalize on their longstanding engineering and design leadership to cement their position worldwide. But that's no longer the case. Today, young upstarts in many product segments, especially from China, can develop world-class design and production capabilities in a short period of time. In some cases, they are closing gaps with long-established incumbents and becoming market leaders within a decade.

The popular narrative is that three main factors are driving this: (1) blatant copying of intellectual property (IP), (2) governments pressuring companies to share technology in exchange for rights to do business, and (3) normal knowledge spillover as workers move from multinationals to local companies.[1] But other, less recognized forces are at play, and they are accelerating commoditization and making product differentiation increasingly difficult to sustain.

Knowledge, particularly the tacit know-how that takes years to develop, now flows through pathways that we take for granted. It is embedded into the tools used to design and manufacture products, and it is incorporated into the building blocks that are used to build more complex systems. The implications are profound. Perhaps the biggest implication is that, armed with this knowledge, young competitors can skip years of practice and experience building, and become competitive threats almost instantly.

Making Complex Things Easy

Sophisticated production and automation tools are at the heart of many manufacturing processes. Their designs are based on years of scientific research and development (R&D). They take things that are hard to do — for example, making electronic devices that have dimensions on the scale of tens of atoms — and make them routine. Specialized tools contain a lot of know-how, and the procedures for using them can speed development cycles by turning the science into simply a matter of following a recipe. The tools make the process repeatable and take out the variability and risk. This can lead to rapid commoditization of whole product areas: All you need is the money to purchase the tools.

The problem is particularly acute in high-tech manufacturing sectors such as semiconductors, flat-panel liquid crystal displays (LCDs), and light-emitting diodes (LEDs), but we can also see the effect in such diverse areas as precision assembly tools, gene sequencing, and computer-generated visual effects for movies.[2] When I worked at IBM Corp. in the early 1990s, we used to refer to these sectors as "kamikaze industries." (See "About the Research.) It was difficult to sustain investments in R&D in fields where know-how was transmitted to competitors via tools — we saw it as a form of economic suicide. Know-how dissemination led to rapid commoditization; companies with low capital or overhead costs could enter a market without massive investments in R&D.

The transition in integrated circuits during the late 1990s from aluminum to copper wiring offers a good example. Even though copper was known to be a better conductor than aluminum, it faced a serious technical hurdle: Copper atoms migrated into the insulating layer of chips, leading to bad connections and chip failure. IBM spent years researching how to overcome this challenge before becoming the first company to use copper interconnect wiring in silicon microchips, a development that was heralded as a major innovation. But IBM's technical advantage was short-lived. Within two years, a semiconductor tool supplier it had worked with to develop the process started selling the same capability. Although the supplier had been contractually prohibited from selling its technology for two years, once that time period was over there was nothing stopping companies from Taiwan and elsewhere from replicating IBM's process, and many did.[3]

A similar shift has taken place in LCD flat-panel displays used in televisions, computer screens, and smartphones.[4] The screens are manufactured in highly automated factories that similarly rely on specialized tools, and anyone who buys the tools and has the patience to learn how to use them can enter the business. My interviews with several flat-panel makers highlighted how toolmakers and customers worked collaboratively to solve production problems.[5] Supplier employees worked side by side with their customers to ramp up the factories into production. They played an essential role in the development of local capabilities, and they could then use the know-how they developed with subsequent customers.

Industries where tools play such an essential role in manufacturing competitiveness lead to another phenomenon called the "latecomers' advantage."[6] In 2004, for example, I visited seven fifth-generation LCD facilities. Some had been running for a year or two, while others had just begun production. The same companies supplied tools to all the facilities. The toolmakers learned how to make new production processes work in the early factories, and then they passed along what they learned to the ones that came later. One of the factories found a more efficient method of injecting liquid crystal material, using "one drop filling."[7] The factory owner worked closely with the tool supplier to fine-tune the method. For newer factories, the learning curve was minimal — they could buy the complete turnkey solution from the supplier, who had become an expert.

Here lies the dilemma: While early customers stand to benefit by working with toolmakers to push forward the frontiers, they quickly lose this advantage. Because development costs are high, toolmakers need to sell their technology broadly. Only then can they justify the substantial investments and risks associated with pushing the boundaries on new technology.

The amount of commoditization pressure a company faces depends on the number of complementary assets it needs to operate successfully (see

ABOUT THE RESEARCH

This article is based on more than 50 Harvard Business School case studies developed between 2009 and 2017 about the semiconductor industry, the LCD flat-panel display industry, the LED industry, and other technology-intensive industrial product companies in the consumer, automotive, and aerospace sectors. Some of the cases focused on the development or loss of competitive advantage for very specific capabilities or focused on design tools that raised the level of abstraction. I also interviewed dozens more companies and visited the production facilities of many other organizations that had a high dependence on sophisticated production and design tools and were able to document specific examples of know-how transfer. The article also draws on many years in industry, during which I witnessed the struggle to control the diffusion of proprietary knowledge in advanced manufacturing processes.

"Complementary Assets: What Do I Need Besides the Tool?") and how difficult they are to replicate. Such assets could be other tools or specific operating capabilities. If a producer needs to use a tool in conjunction with other tools or recipes (as is common in the most advanced semiconductor processes), it's easier to protect the product space. However, if the tool is the keystone and complementary assets are easy to acquire, commoditization is the likely outcome.

This is exactly what happened with the production of LEDs used in energy-efficient lighting. Once a company had the production tool, the other capabilities were relatively easy to line up. The tool suppliers, who wanted to sell as many machines as possible, got help from the Chinese government, which was happy to support a disruptive new industry with subsidies for tool purchases. Yet once overcapacity and brutal commoditization set in, hardly anyone except the toolmakers made money. A senior manager at one of the major European LED manufacturers complained that his company was pushed out of high-volume market segments and had to retreat into niche markets. Even that was difficult to sustain over time.

Gene sequencing followed a similar path.[8] The key competitive advantage of BGI, a gene-sequencing company based in Shenzhen, China, was its ability to raise the capital to purchase the latest sequencing machines that embedded the difficult process steps. Once it had the machines, it hired computer "gamers" and trained them to provide the programming support. This enabled the company to drop the cost of sequencing dramatically and turn it into a commodity. Other Chinese companies followed a similar path, turning China into a "DNA superpower."[9]

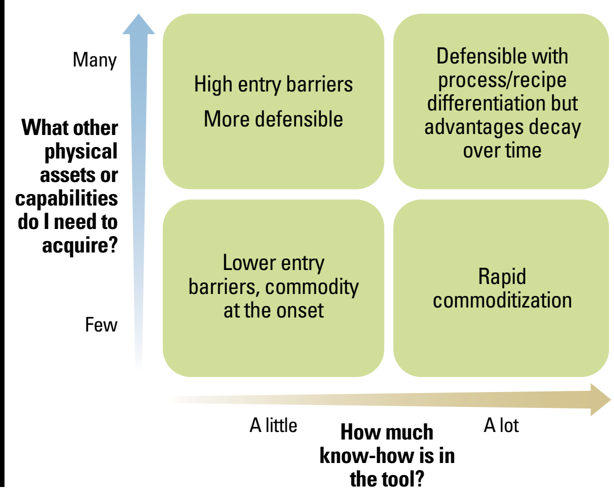
Lowering Entry Barriers

The ability to communicate detailed information about the design and manufacturing process of a physical product is fundamental to high-volume production. Before the era of computerization, this was done with hand-drawn engineering drawings. Computer-aided design (CAD) tools started by automating the drafting processes, but as they advanced they opened the door to modeling and simulation tools, which put sophisticated product design capabilities in the hands of engineers. At the time, nobody really thought of CAD as a way of transmitting know-how. However, while preparing a case study on the growth of a Chinese motorcycle maker in 2010, I was struck by the role CAD and computer-aided manufacturing tools played during the imitation phase of this industry, when companies were aggressively copying Japanese motorcycle parts and assembling them into complete bikes.[10] The widespread availability of AutoCAD, the pioneering PC-based CAD program, was transformational. Small shops scanned parts they were copying and put them into AutoCAD models. Then they could make refinements and drive computerized production tools.

In the motorcycle and auto industries, CAD tools enabled companies to design parts and assemblies, but the ability to develop and refine whole mechanical *systems* (for example, tuning a vehicle's thermal or vibration properties) was a lot more complicated. Enter computer simulation tools, which can evaluate the mechanical and dynamic properties of a complex assembly, such as a complete engine or a transmission. With the latest computer-aided engineering tools, engineers have the ability to identify

COMPLEMENTARY ASSETS: WHAT DO I NEED BESIDES THE TOOL?

In assessing commoditization risk, companies must address two key questions: How much know-how is in the tool, and what other complementary assets do I need? If the tool embodies a lot of know-how and requires few complementary assets, the likely result will be rapid commoditization pressure. The need for complementary assets and capabilities will make an area more defensible. Under the conditions in the upper left quadrant, with little embodied know-how and many required complementary assets, one can benefit from high entry barriers.



potential problems (such as noise or vibration) and then use simulations to refine their solutions.

Chinese carmakers are the poster children for this type of evolution. Ten years ago, vehicles produced by such companies as Shenzhen-based BYD Auto Co. Ltd. or Wuhan's Dongfeng Motor Corp. were no match for products made by German, Japanese, or U.S. companies. But recently they have begun offering cars with homegrown six-speed dual-clutch automatic transmissions, turbochargers, and other features that would previously have taken a generation of engineering experience to develop. Over the past decade, these Chinese companies have become quite competitive with Volkswagen, Honda, and General Motors (which is remarkable, given the fact that BYD didn't enter the auto market seriously until 2003).[11]

Sophisticated design and simulation tools are *de rigueur* for modern product design. Tool suites that allow companies to analyze structures, noise and vibration, acoustics, thermal behavior, fluid flow, motion, and dynamics have democratized design. They have lowered the entry barriers in engineering-intensive sectors, automated the process of cumulative innovation, and allowed new market entrants to stand on top of a pyramid of earlier innovations. In short, they have unleashed a powerful force that's driving commoditization in globalized markets.

The Rising Level of Abstraction

At its most basic level, programming is a set of 1's and 0's that tell circuits what to do. But if you had to worry about the details every time you wrote a program, you would miss the bigger picture. Symbolic languages and more advanced methods using objects and classes have made programming increasingly easy. Some have gone so far as to say that the history of computer software can be described in terms of rising levels of abstraction.[12]

Greater abstraction has been a strong theme in other industries as well. Smartphones and tablets, with their sensors, touch-screen displays, and programmability, have become crucial building blocks for tools that can do a wide range of things, including monitor the health of patients, control machines, and tell microsatellites traveling through space what to do. Cloud computing platforms allow even further abstraction. You don't need to have your own data center — you can plug into a service that does all the low-level work. Abstraction gives us access to powerful technology building blocks and frees us from having to understand how they work.

The New Rules of Competition

Given the profound implications of embedded knowledge flows for high-tech commoditization, it's critical for managers to understand and address their vulnerabilities. New entrants in technology sectors, especially from China, will have "starting points" that formerly took years or even a generation to develop. In some cases, upstarts will have the ability to acquire the complementary assets quickly; in other cases, they may be constrained by regulation, access to intellectual property, or the inherent difficulties of absorbing and managing complexity. Nevertheless, established companies should anticipate more pricing pressure as production capacity enters the market. Chinese entrants, which have an enormous domestic market within which to practice and refine their production processes, will use scale to reinforce their cost advantages.

What can managers do to protect their proprietary advantage? What types of product differentiation will be defensible over time? Here are several strategies companies have used to cope with commoditization pressures.

Rather than worrying about the commoditized parts of the value chain, emphasize complex systems design and focus on protectable areas. Many companies have adopted this approach, especially where the product can be separated into commoditized and proprietary elements. GE Aviation, for example, sources many of its components (such as easy-to-duplicate parts for its commercial jet engines) in lower-cost regions but makes what it considers to be critical parts (such as ceramic matrix composite blades and combustors) itself and performs final assembly in its own factories. GE's complex systems integration capability is hard to replicate, at least for now. Other companies, such as IBM, periodically rebalance their portfolios and exit commoditized sectors.[13]

In sectors where know-how in tools is high, differentiation will depend upon pushing the design frontiers of what's possible and scaling

quickly. If you are dependent on sophisticated tools, it makes sense to push beyond the tool capabilities to keep competitors at bay. Chipmakers such as Intel Corp. and Taiwan Semiconductor Manufacturing Co. do this out of necessity. They try to stay at the frontier of tool capabilities by pushing advances such as vertical transistors (known as finFETs, for their finlike structure), which draw on deep physics and materials science expertise.[14] The complementary assets needed to compete in new technical areas (such as skills in atomic-scale modeling) are difficult to acquire, which slows down the commoditization process.

Focus differentiation on detectable IP, and aggressively defend it. Even in the hypercompetitive LED market, some companies have successfully carved out a profitable position by protecting specific chemical combinations of materials and physical device designs used in manufacture. Nichia Corp., for example, a Japanese electronic materials company based in Tokushima, produces patented LEDs in parts of the color spectrum that are hard to make (in order to produce white light) and has aggressively defended its patents.[15] As obvious as this strategy may seem, it makes sense only when dealing with innovations where the underlying invention is detectable; there is no benefit to disclosing otherwise undetectable/enforceable inventions. It also suggests that defensive disclosures — publishing methods or designs to prevent others from patenting them — can be an effective strategy. While IP enforcement is still problematic in markets such as China, the situation is likely to improve as Chinese companies come to realize that they need protection as well. Such has been the pattern in the telecom equipment sector.[16]

Protect process know-how in hard-to-detect areas. This action requires companies to review their trade-secret policies with a particular focus on protecting knowledge of and about complementary assets, and then documenting and enforcing those policies. It also suggests that companies think carefully about what to patent versus what to protect as a trade secret. (See "What Should Companies Protect?")

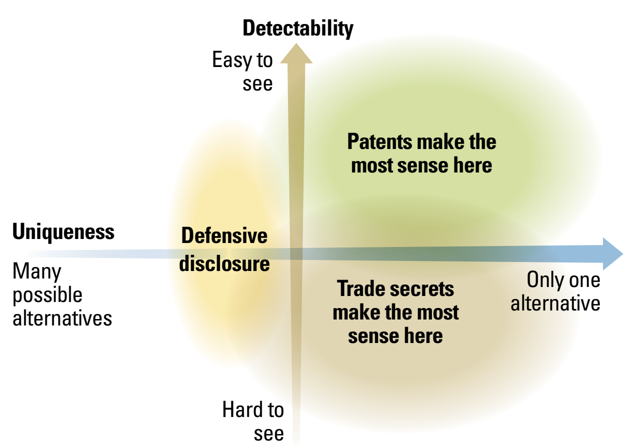
Ironically, many companies that once benefited from know-how embodiment in tools in Asia have become aggressive in protecting trade secrets, going so far as to tightly control whom they allow to visit their production facilities. An LED manufacturer that I studied in 2015 has become heavily involved in patent-infringement litigation. On a prearranged tour last year of the most advanced semiconductor factory in Taiwan, we were told we were welcome to visit the tranquility garden, but the production floor was completely off-limits. Although executives expect that their know-how will eventually leak out (mostly through targeted hiring by competitors in China), they hope to delay this for as long as possible.[17]

Yet in some businesses, tools can only do so much. Complementary assets can be a critical differentiator. I recently saw this at a diamond-cutting operation in Southeast Asia. In the past, diamond cutting required specialized skills and was performed primarily by trained artisans, many clustered in Israel or Antwerp, Belgium. But new, computer-driven-analysis tools and laser cutters have disintermediated the artisans and turned diamond cutting into a commodity. The high-end producer I visited still had sophisticated jewelry design capabilities that enabled it to use diamonds in unique ways, and it had deep sourcing and distribution relationships. These — not its cutting expertise — were the factors that protected its market position.

Sophisticated production and design tools that incorporate know-how streamline the innovation

WHAT SHOULD COMPANIES PROTECT?

Patents make sense when there are limited ways of implementing an invention and when it is possible to detect that the patent has been used. If use is not detectable (as is often the case with a manufacturing process), patents serve only to tell others how to do something; instead of patenting, it may be better to protect an invention with a strong trade secrets policy. If there are many ways of doing something, it might be better to use defensive disclosure, publishing the idea so that others can't block you by patenting it at a future date.



and production process. They make it easier for competitors to sit on top of the pyramid of accumulated knowledge that in turn makes the manufacture of technology-intensive products possible. This shift will spawn new global competitors and bring new choices to consumers. But it will also present grim and potentially existential challenges for established market leaders. The faster onset of commoditization will raise the bar on innovation strategies and the importance of complementary assets.

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