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McKinsey on Semiconductors

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McKinsey on Semiconductors is written by experts and practitioners in McKinsey & Company's Semiconductors practice.

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Introduction

André Andonian,
Harald Bauer, Sri Kaza,
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and Nick Santhanam

Given the enormous and endlessly expanding role played by technology in the world economy, the layperson might be forgiven for assuming these are easy times for semiconductor companies. As our inaugural edition of *McKinsey on Semiconductors* notes, things are rather more complicated.

On the one hand, the semiconductor industry is certainly enormous: it has grown to almost $300 billion, driven by a cycle of continuous improvements in technology, growth in demand, and innovation in end-use applications. On the other hand, as the authors of “Creating value in the semiconductor industry” note, while the semiconductor industry contributes disproportionately to growth in US labor productivity and delivers tremendous value to consumers, most chip makers capture only a small percentage of the value they help create. In fact, excluding Intel, which made handsome profits indeed, the industry destroyed approximately $47 billion in value from 1996 to 2009. If semiconductor players are to meet market pressure to grow, they must lead convincingly on technology in their segment or grow in subsegments where they can differentiate themselves.

China is a critical source of growth for nearly all established semiconductor players. Luckily for them, China has not yet developed a strong indigenous semiconductor business, despite 20 years of effort. However, the forces that have held China back are weakening, and the government has launched a slate of initiatives aimed at developing strengths in three important new semiconductor markets: cloud computing, the "Internet of Things," and electric vehicles. The result, as the authors of "The challenge of China" show, is that China will fight to hold on to its own market and may even compete for the developed-world market, too.

Many of the industry's challenges relate to keeping up with rapacious demand for new and better products. So it is ironic that "LED at the crossroads: Scenic route or expressway?" concerns an undoubted technological advance that is making extraordinarily slow progress into general use. The authors discuss five barriers to adoption that, if addressed, could lead to an LED-dominated lighting marketplace by 2015.

Indeed, one might say the whole industry is at a crossroads: breakthrough innovations are needed to advance to the next node. Costs for manufacturing equipment are rising exponentially. Few can afford to compete on the technology frontier created by Moore's Law. And growth is concentrating only in select segments such as smart phones and mobile computing. Of course, the challenges differ by subsegment. "The evolution of business models in a disrupted value chain" proposes models for success in the fabless segment, explores the limits of vertical disintegration, and discusses how miniaturization is bringing success to outsourced semiconductor assembly and test (OSAT) players.

One piece of the industry has been free from Moore's Law's punishing investment implications: the analog segment has historically been stable and profitable. In "Will analog be as good tomorrow as it was yesterday?" the authors examine the implications of the industry's first 300mm-based manufacturing capacity. They ask whether this stability and profitability will endure.

Despite many unsettling strategic issues, all semiconductor companies must still find ways to improve bottom-line results in the near term. The supply chain offers one important opportunity. Obviously, an industry that combines high capital intensity with long cycle times and a position far down the value chain will suffer supply-chain difficulties. But some are avoidable. As the authors of "From source to drain: Fixing the supply chain" note, supply-chain performance varies significantly, even within the same applications. The authors analyze excellent supply chains and discuss what it takes to create one.

Pricing represents another opportunity. The semiconductor industry, in which price declines are as certain as death and taxes, is particularly prone to discounting to maintain market share. The authors of "Getting customers to say, 'The price is right!'" explain how companies can school their sales forces to get customers to see products through the lens of their value, rather than their cost. Only through value selling, they suggest, can the discounting cycle be broken.

Next, we take on research and development. How can companies overcome a long history of time and budget overruns in the face of ever-changing customer expectations? The authors of "Getting Mo(o)re out of semiconductor R&D" explain that getting R&D right implicates many functions, including marketing, sales, production, and even supply chain, and so urge a broader view of the product-development process, in which all involved functions are engaged. By examining one or two end-to-end cycles in, say, a new feature, a team can observe and address all the touchpoints, loops, interfaces, and delays throughout the organization, reducing time to market by as much as 30 percent without compromising quality.

We close this issue with "Mastering variability in complex environments." The combination of semiconductors' complexity and the pace of industry change make variability—a deep challenge to profitability—very difficult to manage. What can be done? The authors discuss a way of quantifying the impact of changes in lead time and utilization on variability that can help manufacturers manage that variability beyond what can be done with traditional methods.

We hope these essays encourage you on your journey toward excellence. We invite comments at McKinsey_on_Semiconductors@McKinsey.com.

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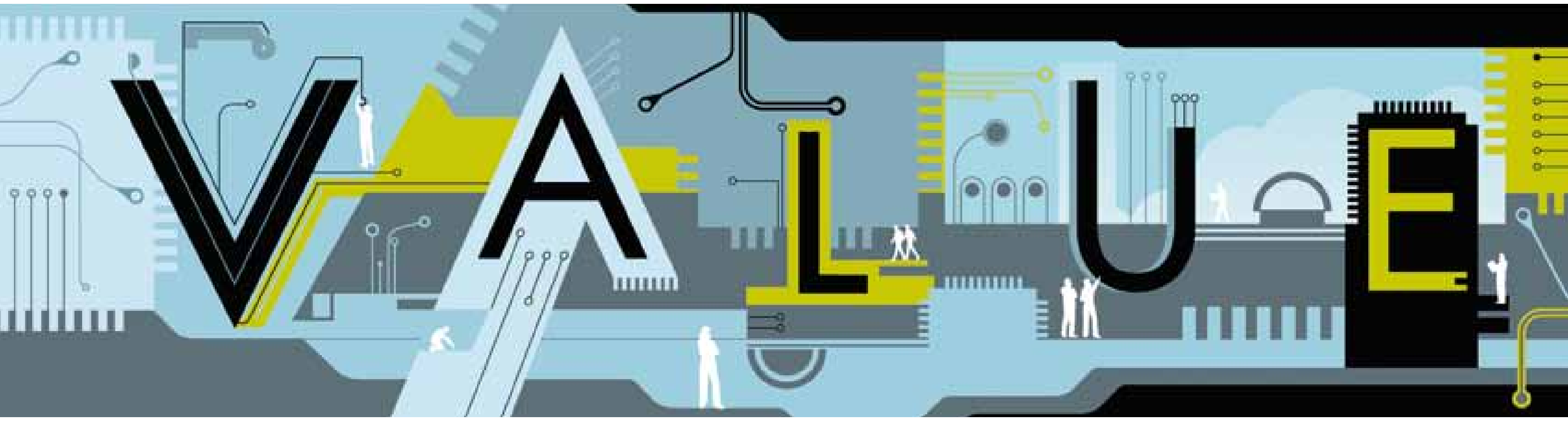


Creating value in the semiconductor industry

In light of increasing consolidation throughout the semiconductor value chain, companies that wish to succeed must move quickly to close capability gaps.

Stefan Heck, Sri Kaza, and Dickon Pinner

Despite its moderate size, the semiconductor industry contributes disproportionately to growth in US labor productivity and delivers tremendous value to consumers. The industry, along with the electronics industry it does so much to power, contributed more than 25 percent of total US productivity growth from 1995 to 1999—more than any other sector. That four-year period outshined overall productivity growth from 1987 to 1995, according to an analysis published by the McKinsey Global Institute.[1]

Much of the tremendous growth seen in the electronics industry over the last three decades comes directly from the increasing power and decreasing price of semiconductors, a function of Moore's Law.[2] This performance improvement enables the electronics industry to continually produce devices and systems that are smaller, more powerful, and richer in features at lower prices. It has famously been noted that if the automotive industry had achieved similar improvements in performance in the last 30 years, a Rolls-Royce would cost only $40 and could circle the globe eight times on one gallon of gas—with a top speed of 2.4 million miles per hour.

However, most chip makers capture only a small percentage of the tremendous value they create; consumers receive the lion's share. Indeed, despite its large positive impact on overall economic growth, the semiconductor industry (excluding

[1] *US productivity growth 1995–2000: Understanding the contributions of information technology relative to other factors*, McKinsey Global Institute, October 2001.
[2] According to Gordon Moore, a founder of Intel, the number of transistors that can be fitted into a single chip doubles roughly every two years, resulting in both faster performance and lower cost.

Intel) destroyed approximately $47 billion in value for shareholders between 1996 and 2009 (Exhibit 1). To put that figure, and the significant disparity seen in the industry, into context, Intel alone created about $57 billion in value during that same time period.

The economic challenges that the semiconductor industry faces can be attributed to a confluence of two factors: cyclicality, and rising costs in R&D and on the capital-investment side of the ledger, due to the increasing costs of upgrading existing fabrication plants and building new ones.

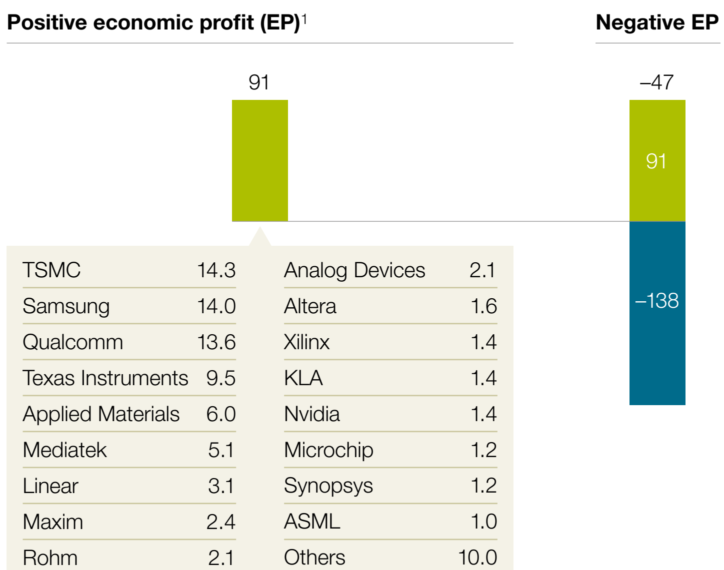
The cycle, while bad for the industry, is in some ways a blessing for underperformers, who have been able to stay in business because the profits they generate during a cyclical upturn enable them to sustain their operations during a downturn and attract funds for capital investments beyond market requirements, which initiates the next cyclical downturn. Government interest in building semiconductor industries—most recently in China and India—accentuates this problem.

As for R&D, chip makers invest heavily, driven to meet the expectations of Moore's Law: costs have

Exhibit 1

The semiconductor industry, excluding Intel, destroyed $47 billion of value from 1996 to 2009.

$ billion



TSMC	14.3	Analog Devices	2.1
Samsung	14.0	Altera	1.6
Qualcomm	13.6	Xilinx	1.4
Texas Instruments	9.5	KLA	1.4
Applied Materials	6.0	Nvidia	1.4
Mediatek	5.1	Microchip	1.2
Linear	3.1	Synopsys	1.2
Maxim	2.4	ASML	1.0
Rohm	2.1	Others	10.0

[1] Positive EP in each year of the time period. In addition, Intel had a positive EP of $57 billion during this period. EP is calculated as net operating profit less adjusted taxes – (capital charge, where capital charge is invested capital at previous year end × weighted average cost of capital).

Source: Corporate Performance Center Semiconductor Database; McKinsey analysis naturally risen along with the ever-increasing complexity of the chips. In addition, the investment hurdle for building a state-of-the-art chip fab continues to rise.

All that said, it is important to remember that the $47 billion of destroyed value is an aggregate figure made up of many losers and several disproportionate successes. Indeed, in many segments, the top performer generates more than 100 percent of the total value. How do the top performers succeed? They implement operational-improvement programs for product lines that can hit acceptable targets for return on invested capital (ROIC), and judiciously divest those that cannot.

Companies that wish to thrive must follow this example. They must optimize for ROIC rather than share or gross margin, a process that entails identifying improvement levers relating to each component of ROIC and designing initiatives targeted to each. Lean operations approaches, including best-practice manufacturing techniques, exert direct impact on ROIC and are therefore key levers in this first step.

The companies that have successfully followed this two-step model have achieved improvements in ROIC in the range of 5 percentage points. Some companies have improved ROIC by as much as 20 to 30 percentage points.

Understanding the sources of value destruction

Although an analysis of income statements shows a number of profitable players in the semiconductor industry, most players are not able to generate economic profit; that is, their ROIC lags behind

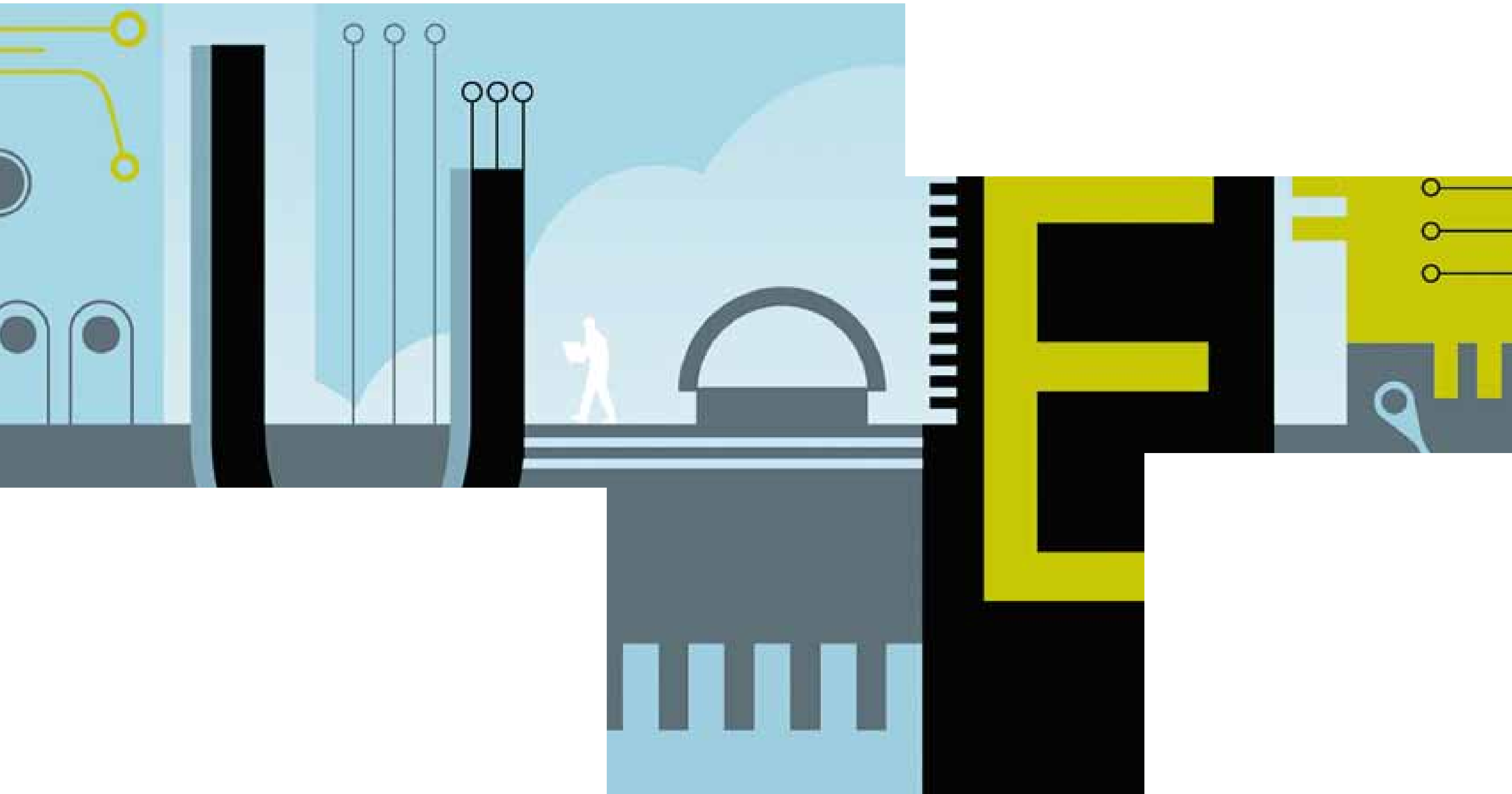
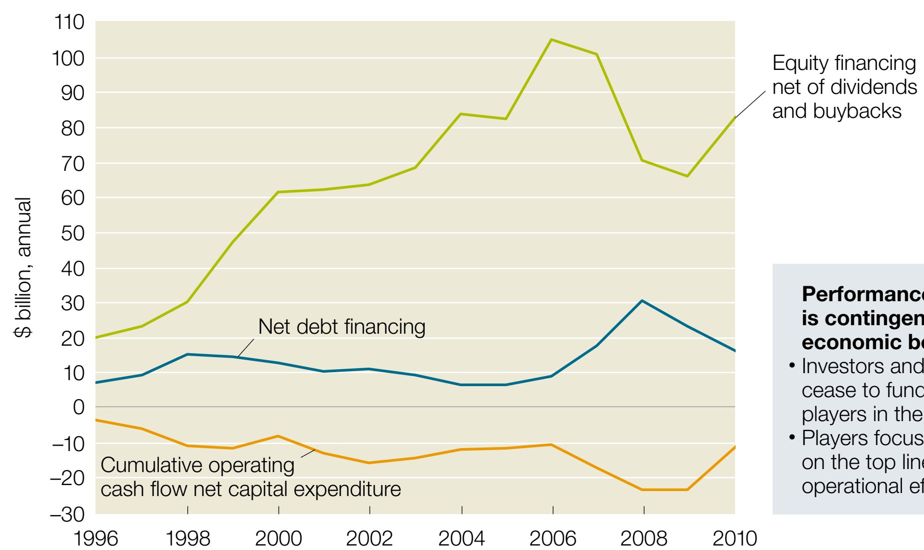


Exhibit 2

Financing continues to flow from private investors and governments as poor performers fail to deliver.

Sources of financing for poor performers[1]



Performance improvement is contingent on change in economic behavior

- Investors and governments cease to fund value-destroying players in the future
- Players focus not only on the top line but also on operational efficiency

[1]This includes the 59 players with the lowest average economic profit/revenue.

Source: Compustat; Corporate Performance Center analysis

their weighted average cost of capital. Indeed, disaggregating the industry by business model and subsegment reveals that in most segments, only one or two players create value.

As we have indicated, the industry as a whole has struggled to generate economic profit because three factors present unique challenges to chip manufacturers.

Historically, the semiconductor industry has shown strong cyclical behavior. During a typical upturn of one to two years, most companies generate profits, which they use to sustain their operations during the downturn. In addition, many players use their strong performance during an upturn to entice investors in the public markets or get new loans to fund capital investments; in many cases, governments subsidize these refinancings (Exhibit 2).

But precisely because investment runs ahead of market demand in the upturn, the period is followed by a longer downturn or a very slow growth period, during which poor performers struggle. There is some evidence to suggest that both the amplitude and time frame of the industry's cyclicality is moderating, but it is likely that some degree of cyclicality will remain.

The skyrocketing costs of R&D and the increasing amount of capital required to build a state-of-

Exhibit 3

Fewer logic integrated device manufacturers are able to sustainably invest in leading-edge nodes.

[1]Nanometers.

Source: iSuppli; literature search; McKinsey analysis

the-art fab add to the industry's economic challenges. Chip makers continue to pour money into R&D as new designs and process technologies become increasingly expensive to develop. In 2009, R&D spending amounted to approximately 17 percent of industry revenue for semiconductor companies (up from 14 percent a decade earlier) versus 3 percent for automakers, to take one example. The cost of building leading-edge fabs continues to increase as well; for example, the average 8-inch fab costs $1.6 billion to build, while a state-of-the-art 12-inch fab costs $3 billion to $4 billion. Similarly, the costs for developing process technologies on new nodes is increasing dramatically; for example, the average cost of developing a 90-nanometer logic process technology is approximately $300 million, while the cost of developing a modern 45-nanometer logic process technology is approximately $600 million, representing a doubling of spend in roughly five years (Exhibit 3).

In response to these higher costs, many semiconductor companies have resorted to "fab lite" strategies, outsourcing an increasingly large fraction of their chip production to dedicated manufacturing foundries. Although this has resulted in an overall net reduction of capital expenditures in the industry, from an average of approximately 27 percent of revenues (from 1996 to 2001) to approximately 20 percent of revenues (from 2002 to 2009), it has also led to intense cost pressure on chip makers that continue to handle all their manufacturing in-house (Exhibit 4). The shift of manufacturing to Asia has created additional cost pressures on those that have yet to transfer operations to lower-cost locations.

Prices also remain under pressure in the industry as consumer applications become the main force driving the semiconductor market. The much higher elasticity of demand as prices decline has further accelerated the erosion of average selling prices.

All these pressures are intensified by the shift in the end-user market to Asia. Furthermore, the lack of a "killer app" on the horizon—and the slower growth of traditional large, high-growth markets such as PCs and mobile phones—means that the economic pressures on the industry are not likely to abate anytime soon.

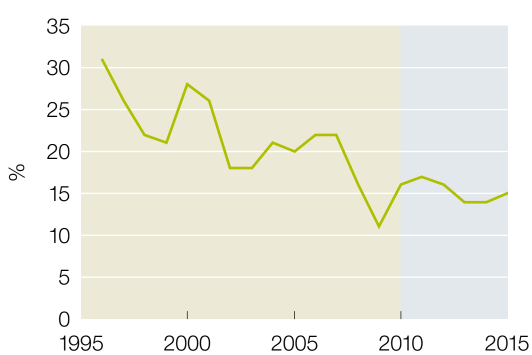
Learning from the top performers

A handful of semiconductor players have consistently generated a disproportionate amount of value in this industry. An analysis of the key attributes of these companies, as well as those of the leading players in other industries, suggests the two major lessons noted earlier for those who seek to capture economic profits in semiconductors: successful players work to improve ROIC where it can be satisfactorily

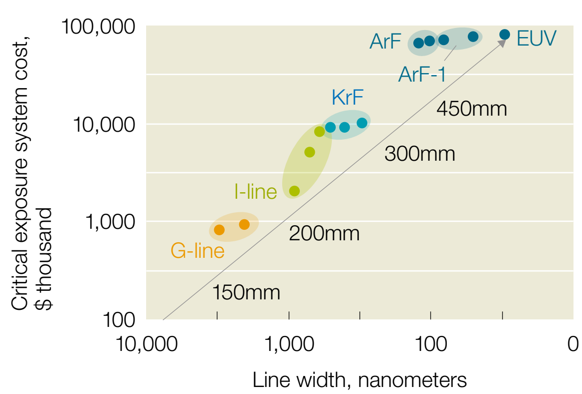
Exhibit 4

'Fab lite' strategies have reduced capital expenditures, and at the same time, overall capital costs are rising sharply.

Capital spending/semiconductor revenue is decreasing . . .



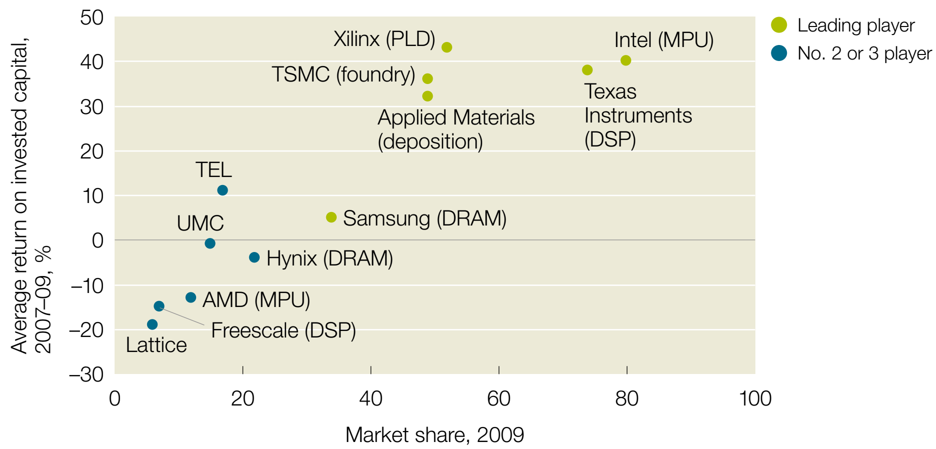
. . . even though capital costs are rising



Source: IC Insights; IC Knowledge

Exhibit 5

A high segment market share enables companies to shape their future and earn higher returns.



Source: Corporate Performance Center Semiconductor Database; iSuppli; Gartner

improved, and they aggressively prune product portfolios of businesses that do not look likely to become sufficiently profitable.

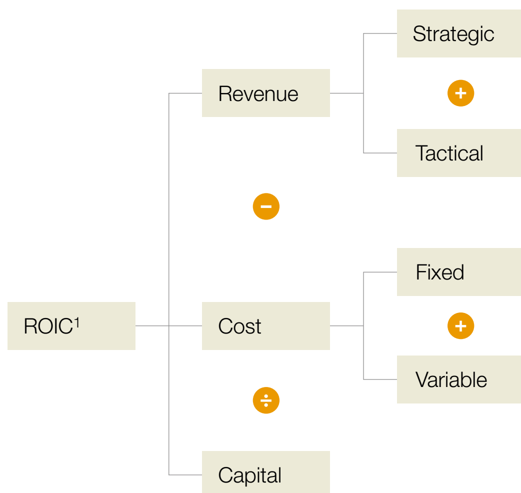
As far as ROIC is concerned, top performers focus on changing the dynamics and structure within a given segment as they seek to build leading positions early on. Acquiring and holding a market share of 40 percent or more within a segment enables companies to drive higher profits (Exhibit 5). Such companies typically have closer relationships with key customers, advanced R&D processes that yield better innovation road maps (which are also more closely aligned with the key value drivers for their segment), deeper insight derived from having a more complete picture of where the market is going, and in many cases, a greater ability to maintain margins through downturns.

To achieve this kind of performance, semiconductor companies must optimize ROIC by executing operational-improvement programs, including but not limited to making lean operational improvements, targeting profitability (rather than other measures), improving asset utilization, and tuning their capital-asset strategy (that is, make versus buy) to further improve return on capital. To target areas for improvement, a detailed ROIC tree can be used to disaggregate the components of revenue, cost, and invested capital and thus identify the main value-creation levers for each component. Exhibit 6 lists examples of value-creation levers and the impact that these levers help companies achieve.

By helping companies implement lean-manufacturing techniques, we have assisted more than 10 semiconductor companies in increasing the throughput of their fabs by 20 to 30 percent (with minimal additional capital expenditure). Naturally, this has been a significant driver of improved ROIC, as well as incremental gross margin. These gains have been achieved by

Exhibit 6

Companies have employed a number of strategies to achieve impact.



Key levers to drive ROIC

- Develop products and drive efficiency and effectiveness in new-product introduction
- Employ a new market-development strategy

- Pricing: improve discipline and value communication
- Sales-force effectiveness: optimize coverage and productivity of field sales force
- Account profitability: realize value from investing in key accounts

- Reduce general and administrative costs, optimize performance
- Optimize R&D spend/portfolio, rationalize products

- Improve fab throughput and drive lean operations
- Employ strategic sourcing focused on total cost of materials
- Optimize consumption to reduce material usage
- Optimize supply chain

- Use fabless/“fab lite” strategy and optimize footprint
- Improve capital-expenditure planning and purchasing strategy

[1] Return on invested capital.

maximizing overall equipment effectiveness, a technique that exposes all the losses attributable to bottleneck machines in a 24-hour period, thereby allowing companies to focus on reducing the largest losses. This technique was as effective in 4-inch, 5-inch, 6-inch, and 8-inch fabs (the older, trailing-edge fabs) as it was when deployed in leading-edge 12-inch fabs.

In trailing-edge fabs, most of the improvements are captured from increasing the uptime of bottleneck machines, for example, by minimizing machine changeovers and setups and optimizing material handling to ensure that a bottleneck machine is never left idle. By contrast, in leading-edge fabs, many of the improvements come from reducing the process time of an individual wafer by tailoring the sequence of tasks of the bottleneck machine to a specific “recipe” (the unique flow of manufacturing process steps required to fabricate the wafer) and eliminating recipe redundancy. For example, dielectric thin-film deposition times can be decreased, with a corresponding increase in the throughput of deposition equipment, by reducing the thickness of excess dielectric material. This has the added benefits of increasing both the throughput of chemical-mechanical-planarization (CMP) machines (because less excess material is removed in the polishing process) and the lifetime of the CMP pads.

Another lever that can help improve ROIC is pricing, and we recommend chip makers use value-based pricing and transactional pricing to drive revenue increases of 2 to 7 percent. Value-based pricing processes enable companies to set prices equivalent to the value perceived by customers by identifying the individual value drivers of a product, interviewing customers to understand the importance of each of these drivers to their purchasing decisions, understanding the degree of differentiation the company possesses with regard to each driver, and translating this value into price. Transactional pricing, by contrast, focuses on minimizing the leakage of value in the final price relative to the list price. This leakage is analyzed with regard to variance (differences in discounting or margin performance), slippage (deviations from established policies, guide-lines, or programs), and structure (suboptimal pricing structures, processes, or delegation levels, resulting in unnecessarily low net prices).

Setting aside ROIC, the second main lever involves proactively managing product portfolios: investing in market segments that are growing, either organically or through acquisition, and divesting segments in which growth or margins are low. In reviewing its portfolio, a company may find that it includes some fast-growing businesses with high profit margins as well as other businesses in which the company has achieved limited suc-cess despite years of investment. Top-performing companies actively evolve their portfolios as markets mature or become less attractive. Rather than engaging in a price war to increase their share of a stagnating market, for example, they drop out of businesses that offer little hope of profitability (Exhibit 7).

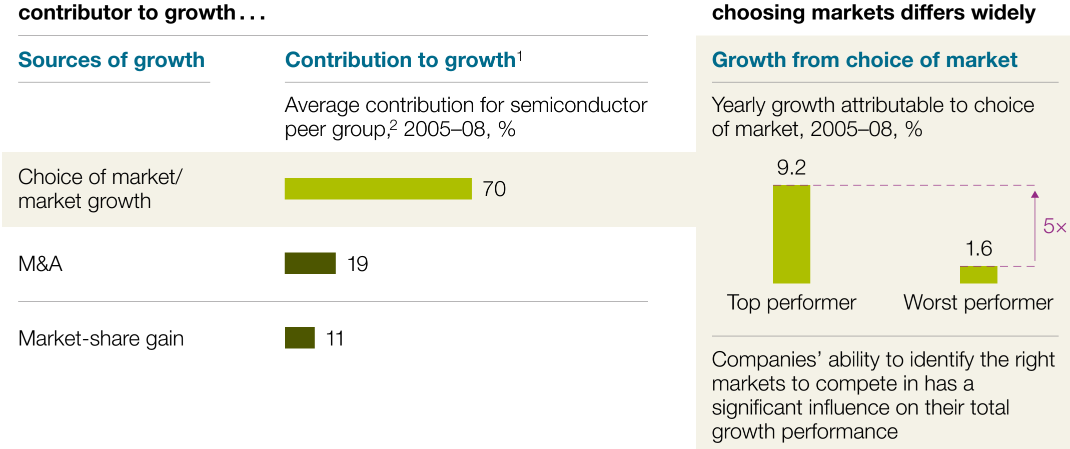
Several top performers have been particularly successful with this approach. Texas Instruments has divested more than 15 lower-growth, lower-

Exhibit 7

It has become even more critical for semiconductor companies to focus on the right markets.

Choice of market is the most important contributor to growth . . .

. . . and companies' performance in choosing markets differs widely



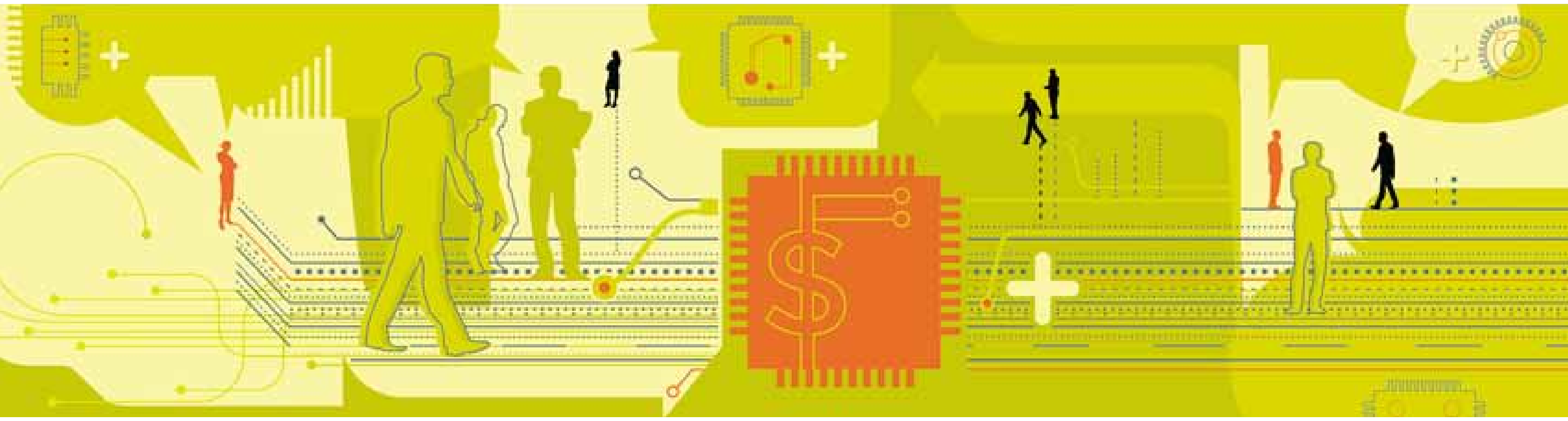
[1]Only positive contributions to growth have been included in the analysis.
[2]AMD, Broadcom, Infineon, Intel, Mediatek, NEC, NXP, Panasonic, Qualcomm, Sony, ST, Texas Instruments, and Toshiba.

Source: Annual reports; McKinsey analysis of granularity of growth margin businesses in the past 15 years (including its DRAM and defense-controls units) to focus on the wireless business, as well as to develop a medical business. Qualcomm focuses on the large, high-growth wireless-handset market and, by controlling intellectual property such as the CDMA and WCDMA chip sets, is able to generate significant profits through licensing arrangements, creating an additional revenue stream that does not entail building chips. Applied Materials' ability to enter key new growth segments (such as rapid thermal processing, copper deposition, and solar) while shifting its mix away from underperforming segments (such as implants) has enabled it to maximize profitability. As these examples illustrate, it is crucial for semiconductor companies to develop solid portfolio strategies and to actively manage their portfolios over time. Put another way, just as the technologies and processes in the fabs evolve, so must the composition of the corporation.

• • •

The inability of many semiconductor companies to create value is one of the key factors driving consolidation throughout the industry's value chain today. Indeed, as private-equity players set their sights on the industry, underperforming companies face a stark choice: they can either follow the lead of top performers and undertake initiatives to improve performance, thus helping shape the industry's structure, or they can leave it to acquirers to step in and drive a new dynamic of value creation. Those that choose the former course must begin by evaluating whether they have the strategic, organizational, and operational capabilities to pursue a performance transformation. If such companies lack these capabilities but still wish to control their future, they must move quickly to close capability gaps before embarking on the journey.

Stefan Heck is a director in McKinsey's Stamford office, **Sri Kaza** is an associate principal in the Silicon Valley office, and **Dickon Pinner** is a principal in the San Francisco office.



Getting customers to say, 'The price is right!'

In a world where too many companies still believe that 'if we build it they will come,' practitioners of semiconductor sales know otherwise. This article lays out the elements essential to extracting the most value for current products by effectively communicating the true value of those products to customers.

Gaurav Batra and Olivia Nottebohm

Keeping the marketing and sales engines humming profitably is a cornerstone of all successful companies. It is especially important in the semiconductor industry, where the leaders in each product segment usually take most of the profits. Things often go wrong when companies feel their market share is threatened. Frequently, the first response of both leading and lagging players is to discount prices. Closer analysis, however, often reveals that this move needlessly dilutes value that could have been retained despite competitive pressure.

In semiconductors, discounting is not just a strategy but an industry norm—a condition that has prevailed owing to an industry adaptation to extremely tight innovation cycles. That is, the larger issue underlying habitual discounting in semiconductors is the acceptance on the part of semiconductor companies that a dynamic built into the industry as a whole will always drive prices down. Companies therefore often fail to address and can even contribute to the shortfall by expecting nothing better. However, companies can begin to reverse this trend by revisiting the value proposition they are offering to customers, specifically to determine whether the true, unique value of their products is being communicated. This is where the journey to value selling begins.

The value-selling approach

We have devoted considerable research and drawn upon extensive engagement experience to create an approach to sales by which companies can better understand their existing value propositions, identify where these are failing them, and make the transition to a customer-centric approach that immediately demonstrates the full value of their products to customers. A value-selling approach allows companies to pursue and capture margin according to the end-to-end value provided to the customer, as opposed to the traditional cost-plus approach. Even in the semiconductor industry—with its engineering culture that is particularly comfortable with cost-plus pricing—most client executives have been pleasantly surprised to see the top-line impact possible from value selling, especially as it requires no changes to the existing product portfolio. In the first year, value selling can add 2 to 4 percent to average selling prices, a number that can grow to 6 to 8 percent in the second year if customer insights are fed back into the design of new products.

Our original findings were based on practical experience. We interviewed dozens of one company's end customers, asking each of them to allocate 100 points among the different factors in their process for making purchasing decisions. The great majority of those surveyed identified price as the most important factor in their final decision. Deeper analysis of those responses revealed, however, that some groups of customers actually cared as much or more about features than about price. It turned out that some customers were knowingly paying more for the client's product than they would have for the next-best alternative. The discovery of this partly hidden preferential-buying behavior led to a conclusion that a sales approach that communicates a holistic view of value could positively affect the way that customers think about purchases.

The transition to a value-based selling approach involves a fundamental change in existing sales approaches and marketing messages. The constituent tactical shifts of the approach are made based on deep-structure interviews with customers, as well as by working to identify the value of the company's offerings. A company adopting this approach will also need to construct a set of new tools for the sales force and build value-selling capabilities in the workforce. Last, it must develop metrics to track sales-force performance over time. A formal transformation program is necessary to sustain the transition; the good news is that the scope can be either narrow or broad, focusing on a single product family or region, or encompassing a program that repositions a company's entire product portfolio.

Identifying value to the customer

Value selling requires, at its base, an understanding of the true value of the product to the customer. Most customers think of value as apparent value—that is, the benefit they receive directly from a purchase. They rarely consider indirect benefits, such as the positive or negative impact of switching costs, or the infrastructure savings that come from sticking to current product lines. In addition, a mind-set has been observed in both companies and their customers by which current prices are expected wholly to determine future prices. Accordingly, unless the product changes, the price should rise only in line with inflation or if particular input costs increase. This generally leads companies to neglect the question of how the value of their products evolves over time.

In all, there are four components to implementing a value-selling approach: developing a new approach to purchasing criteria, building a new set of tools to support the sales teams in the field, developing training to educate sales teams on the new sales approach, and developing metrics and systems to track the sales force's performance over time.

1. Uncovering customer purchasing criteria

The first step in the new direction is a diagnostic analysis aimed at uncovering the key criteria that customers use to make purchasing decisions. This may seem counterintuitive, as company sales and marketing teams would be expected to know these criteria already. Typically, top salespeople do know exactly what matters to their customers, but their less skilled colleagues may not; best practices are not always shared or institutionalized in a form that is useful to less experienced account managers. We begin with interviews to determine the elements that matter most to customers and to understand how these are prioritized. The exercise is highly qualitative, requiring dozens of interviews throughout the customer base.

The diagnostic yields three results: a list of factors that are most important to customers, a ranking of those factors in order of importance, and, critically, an assessment of company performance against those value drivers in any particular product category.

To go beyond articulated preferences, we conduct a conjoint analysis to quantify value drivers at both the individual product level and the broader company level. Typical findings from diagnostics of the sources of value at the *product level* have included these attributes:

- Superior performance with regard to power efficiency, speed, graphic resolution, and so on
- Ease of use and ability to design in, without many additional modifications
- Advantaged size and packaging to enable greater bill-of-materials integration
- A better set of built-in capabilities to reduce the need for additional discrete peripherals, board design, or programming

At the *company level*, we have found that customers derive value from the following elements:

- The reputation of the provider—for example, the value of saying "powered by *x*" or "includes *y* processor"
- Strong development and technical-support capabilities
- Advantaged supply-chain and manufacturing capabilities, resulting in higher product availability, better quality assurance, and superior reliability
- Developer tools and well-established code libraries—for instance, a network of independent software vendors (ISVs) for microprocessors

In a value-selling pilot, one customer said, "If it saves me development cost and improves my time to market by *x* percent, I am not going to go for a cheaper device." This remark neatly sums up the reasoning behind value selling and the source of its impact.

2. The value-selling tool: Communicating quantifiable value to your customer

Once a company understands the real value of its products to its customers, it must develop easy-to-use tools to guide the sales team in its work. The tools are often mechanisms for quantifying the impact of relevant value drivers and simplifying any calculations the sales team must make. If we consider the example of a company that can deliver a particular product faster than a competitor, its sales force must be able to quantify the value to the client of faster time to market in the specific marketplace into which the product is being sold. A calculation of such specificity can rarely be performed in an ad hoc manner by a sales team in the field.

The team therefore needs an analytic tool that can systematically identify the value created for the customer by the company's product versus the next-best alternative. This identification will come in the form of an assessment that clearly captures the incremental value delivered by the product vis-à-vis competitor offerings (Exhibit 1). The tool must be easy to use, and its analytic mechanism dynamically responsive to the needs of the field. The salesperson must be able to enter a few essential variables reflecting the specific interest of any

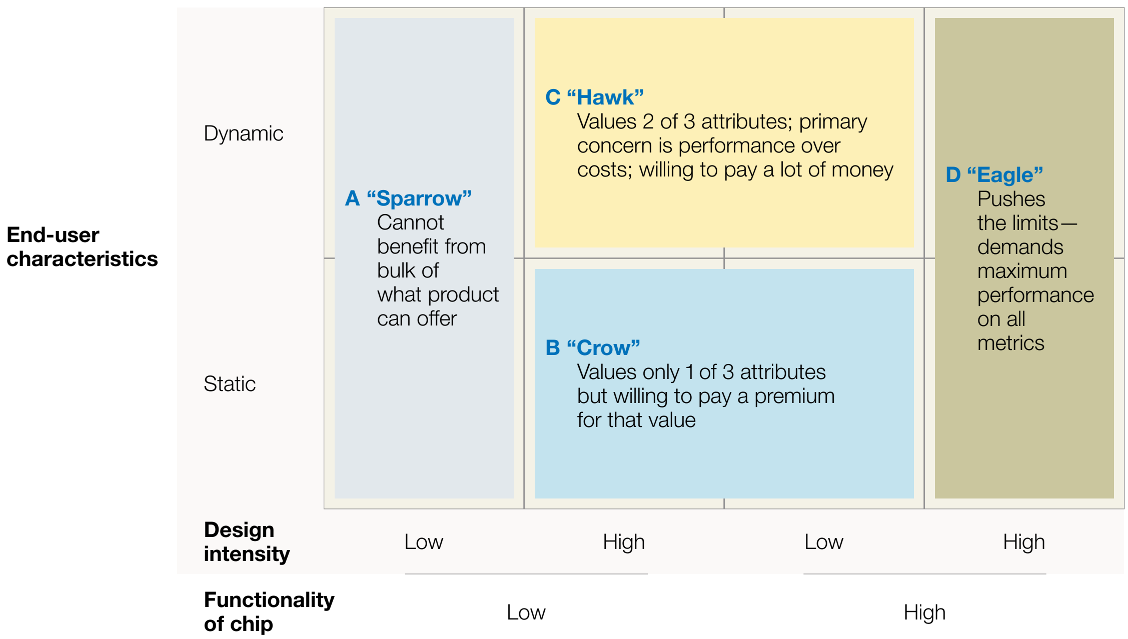
Exhibit 1

Research shows that customers make clear value distinctions for many products.

Source: Customer interviews; McKinsey analysis

Exhibit 2

What customers value differs significantly according to the segment they fall into.



given customer and obtain an assessment of the value of the product to that customer.

Much technical and experiential expertise will be incorporated into the value-selling tool, and this input must be regularly updated with product, customer, and market data. The tool's purpose, however, is a simple and visible demonstration of the power of the value-selling approach. This power lies in value selling's ability to communicate a quantifiable value, based on the drivers that are most important and therefore worth the most to the customer relative to competitive offerings. The approach is entirely oriented to allowing the salesperson to take a customer-centric view. It enables salespeople to provide in a dynamic fashion the information needed by a customer's line-of-business leader or procurement officer in order to make the winning case for their product to his or her boss. The salesperson thus delivers to the customer a transformed value proposition. The message becomes "I'm getting a product worth two to three times its price," rather than "I'm getting a product 10 cents cheaper than the next guy is."

Not all customers are the same: some may share a consistent set of value drivers, while others have variable priorities or find different value in comparable attributes. Good value-selling tools empower salespeople to identify the types of customers they are dealing with and to generate quickly the most convincing value proposition for them. The sales force can adapt to different types of customers without having to improvise value propositions for each customer visit (Exhibit 2).

3. Building value-selling capabilities in the sales force

The value-selling approach represents a new way for the field sales force to relate to its customers. How can you bring this new approach to life for them? Here we believe there are three critical success factors: first, leaders and the sales force must co-create the solutions; second, leadership must visibly model the new approach; and third, salespeople should be allowed to practice new skills in a safe, non-customer-facing environment.

Co-creating solutions

The more the experienced members of the sales force are engaged in the quantification process—that is, in generating the underlying numbers that drive the calculations made by the tools the sales force will use—the more effective the result. There are two reasons for this: first, experienced salespeople understand the dynamics in the marketplace and can use their expertise to improve the tool, and second, they must believe in the calculations that drive the value-selling tools they are being asked to use.

Modeling the approach

The second success factor is no less important than the first. The sales force must feel the inspiration from above. The head of sales for the company must participate in the effort and personally emphasize the need for value selling.

Practicing the approach

Finally, we have found that it is crucial to create a low-stress environment, in which salespeople can practice free of exposure to customers and fears of internal evaluation. Every time we have conducted such sessions, we have discovered that recording the salesperson's customer approach and then reviewing it with them helps prepare them for even the toughest customers. When they see themselves working—and improving—in the new way, salespeople truly internalize the arguments they must make and embrace the value quantifications they will put forward.

Early practice often becomes a learning opportunity, in which the shortcomings of the existing approach are revealed and understood as such. Salespeople usually begin by talking in cost-plus language, rather than adopting a customer perspective. A salesperson may fail to offer quantified comparisons with competitive products, even when supporting data are at the ready. The key is to keep trying: with practice, the new way of working begins to stick.

Value selling requires, at its base, an understanding of the true value of the product to the customer

4. Locking in change by tracking performance

We cannot overstate the importance of metrics to track performance. Simply put, what gets measured gets done. Most successful transformation programs have an engaged program-management office that is aided by efficient IT systems to track progress and assess sales-force behavior on a regular basis. The most successful value sellers use a sequence of workshops, scheduled to coincide with the run-up to new sales campaigns or new product launches, to maintain momentum. These sessions allow companies to share best practices and celebrate successes. In the medium term, value selling can improve average selling prices substantially, reinforcing the approach.

• • •

McKinsey has introduced its value-selling approach in a number of industries, where it is increasingly becoming a key success factor. We strongly believe that this approach has a great deal to offer the semiconductor industry, where customers want to be told precisely what value is being created for them and to know how a product will help them be more successful. In a world where products do not sell themselves, value selling is demonstrating that it can make the crucial difference for companies.

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The challenge of China

As barriers to Chinese competition weaken, local and foreign semiconductor players must consider issues such as intellectual property and knowledge transfer to fully capture opportunities in this important market.

Sri Kaza, Rajat Mishra, Nick Santhanam, and Sid Tandon

Since the late 1980s, the Chinese government has made efforts to build an indigenous semiconductor industry by providing financial incentives, developing talent and technology, and crafting alliances with global players. And though the country has assumed a central role in the manufacture of many computing and consumer-electronics products, its role in the semiconductor sector has remained surprisingly limited. In the industry value chain, China has a strong share in only the assembly-and-test and back-end-manufacturing segments. Aside from these two (admittedly considerable) areas, the country is largely missing from semiconductor league tables.

In fact, today China is primarily a consumer of semiconductors, rather than a producer of them. The country's semiconductor trade association published a report in March 2011 that estimated that the Chinese semiconductor market accounted for fully 33 percent of global supply. The share of those chips used in domestic products accounts for 15 percent of the global semiconductor market. The remaining share is installed in a wide range of export goods. Furthermore, our research indicates that Chinese companies influence the design and other elements of just 1 to 2 percent of finished chips.

It would be logical to expect that a country of China's size would be a leading stakeholder in discussions about technology standards and the designs for next-generation platforms, but that is not the case. Despite consuming 33 percent of the global market for semiconductors, Chinese companies claim less than 4 percent of global revenue in the lucrative segments of semiconductor design and front-end manufacturing.

There are four reasons for this state of affairs. First, China exerts little influence on semiconductor design and selection in major product categories such as mobile phones and laptop computers. The majority of design decisions for these goods are made by global champions—such as Nokia, Acer, and Apple—in their home countries, at the headquarters level.

Exhibit 1

Chinese foundries lack leading-edge technologies because of export controls.

The 1996 Wassenaar Arrangement puts export controls on manufacturing technology . . .

- Until 2010, controls prevented the export of <90nm manufacturing technology to China
- Until 2010, Taiwan restricted the export of <180nm manufacturing technology to China
- In 2010, the Wassenaar Arrangement was updated: controls now prevent <65nm manufacturing technology from being exported to China
- In 2010, Taiwan signed an agreement with China (the Export Promotion and Cooperation Agreement) that allows the export of manufacturing technology that is 2 generations behind leading edge

. . . which has prevented Chinese companies from accessing <65-nanometer (nm) node technology

Chinese foundry

Company	2009 nodes, microns		Number of fabs		
	Mainstream[1]	Leading edge	<6”	8”	12”
TSMC	<0.13	0.045	1	8	2
UMC	<0.15	0.045	1	7	2
Chartered Semiconductor	<0.18	0.045	0	5	1
SMIC	<0.18	0.09	0	5	3
VIS	<0.20	0.09	0	2	0
Dongbu Electronics	<0.25	0.09	0	2	0
FAB	<0.35	0.13	4	2	0
I-NEC	<0.25	0.13	0	2	0
ALTIS	<0.18	0.13	0	1	0
HeJian	<0.25	0.15	1	1	0
Tower Semiconductor	<0.18	0.13	1	2	0
Grace	<0.18	0.13	0	1	0
SilTerra	<0.18	0.09	0	1	0
SSMC	<0.18	0.13	0	1	0
ASMC	<0.50	0.25	2	1	0
Jazz	<0.25	0.13	1	1	0
EPISIL	<0.50	0.25	3	2	0
China Resources	<0.50	0.25	3	1	0

[1]“Mainstream” includes nodes utilized in more than 50% of the foundry’s total capacity.

Source: iSuppli, H1 2009; World Fab Watch 2009; Wassenaar Arrangement Web site, Category 3 list; Semiconductor Equipment and Materials International; *Taipei Times*

Second, the home countries of major semiconductor companies ban the export of leading-edge manufacturing technologies to China. Both the United States and the island of Taiwan prohibit the export of equipment used to manufacture sub-65-nanometer process technologies, which leaves mainland Chinese foundries two generations behind the current 32-nanometer standard (Exhibit 1).

Third, concentrated clusters of semiconductor excellence failed to fully develop in China. Instead of focusing investments on one location, as did the island of Taiwan with Hsinchu Science Park, the Chinese government made investments in multiple provinces, setting up semiconductor fabrication plants as far north as Jilin and Dalian, as far south as Shenzhen, and as far west as Chengdu. In all, fabs capable of producing more than 1,000 wafers per month are spread across 19 cities. Because the industry was so fragmented, government support did not lead to the formation of a vibrant semiconductor ecosystem in any single location.

Fourth, and perhaps most important, foreign players own most of the intellectual property throughout the semiconductor value chain. Applied Materials, for instance, dominates manufacturing equipment, while Intel, Nvidia, and Qualcomm control key parts of integrated-chip design for microprocessors, video cards, and mobile handsets,

Exhibit 2

Lack of intellectual property and know-how remains the only barrier to increased competition from Chinese semiconductor players.

Barriers are weakening	Details
End-system design in China, for China	**Increasing end-user consumption in China is likely to drive local system design** • ZTE became the No. 5 player in mobile handsets in 2010 • Huawei is a top 3 player in all major telecommunications-equipment segments • Lenovo is the No. 3 PC vendor in the world
Declining share of leading-edge nodes	**The effect of Moore's Law on the global semiconductor market is declining** • Leading-edge nodes now represent 14% of total demand for logic chips and microcomponents, making access to manufacturing technology less important • Several large segments, such as analog integrated circuits ($42 billion in 2010) and microcontrollers ($18 billion), are using older technology
Renewed focus on clusters of excellence	**Several Chinese cities are beginning to attain critical mass as clusters of excellence** • Shenzhen, Chengdu, and Dalian have made significant progress • Texas Instruments and Freescale Semiconductor set up manufacturing plants in Chengdu • Intel set up a 90-nanometer fab in Dalian

Issues related to intellectual-property know-how are the only major roadblock

Source: iSuppli; Databeans

respectively. Owning the intellectual property means these foreign players also garner the lion's share of revenues. In the front-end-manufacturing segment, non-Chinese players (for example, Samsung, Intel, and Hynix) earn 96.3 percent of all revenues. In design, foreign players earn 96.1 percent of revenues. Even in the silicon segment, 93.0 percent of revenues go to non-mainland-Chinese companies. China has a decent share in only two areas, back-end manufacturing and assembly and test, where Chinese companies earn 28.6 percent of total segment revenues.

Taken together, these four hurdles have made it difficult for Chinese semiconductor players to compete in the last decade. However, three of those four barriers are now weakening, and with recent events likely to serve as a tipping point, we believe the lack of intellectual property and know-how is the remaining impediment to Chinese semiconductor players' progress. This portends significant shifts in the international semiconductor situation (Exhibit 2).

The emergence of a Chinese middle class is creating a domestic industry—one with export ambitions

The first barrier—the modest influence China exerts on semiconductor design and selection in major product categories—is eroding as a robust domestic market emerges, particularly because first-time consumers of major product categories that use semiconductors do not need leading-edge products. As a consequence, a substantial "built in China, for China" market is taking shape. To get a sense of the scale of this market, consider the following facts: 26 percent of all automobiles sold in the world in 2010 were sold in China. Chinese citizens bought 19 percent of the global PC supply last year and accounted for 18 percent of LCD-TV sales. In the robust global market for mobile handsets, the Chinese commanded 14 percent of unit sales in 2010. And Chinese companies are leveraging their domestic scale to sell outside of China, thereby shaking up league tables further in a number of industries. Lenovo, for example, is now the third-largest vendor of PCs in the world. ZTE became the fifth-largest handset manufacturer in the world in 2010. And Huawei has become a top-three player in all major segments of the telecommunications-equipment market.

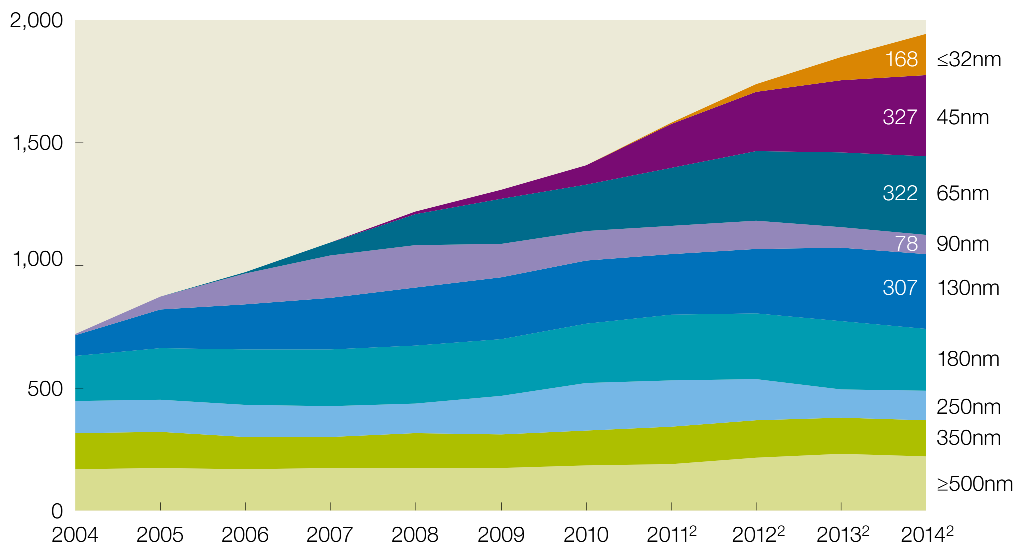
China's emergence is significantly enabled by a declining need for ever-increasing processing speed. As the semiconductor industry moves closer to the physical limits of silicon, fewer devices are relying on truly leading-edge technologies. In fact, leading-edge nodes now represent only 14 percent of total demand for logic chips and microcomponents. There is, consequently, generally less pressure to have state-of-the-art manufacturing technology (Exhibit 3). This opens the door for Chinese semiconductor players. Certain segments of the market have found success using technology that is one or two generations behind the leading edge. For example, analog integrated circuits and microcontrollers (which account for $42 billion and $18 billion in revenues, respectively) are leveraging process technology that is at least two years old. The proliferation of devices powered by less-than-cutting-edge chips means that the playing field for Chinese semiconductor manufacturers is much more level than ever before.

Even if consumers in China become less willing to settle for second-best technology as their affluence grows, share is unlikely to shift decisively back to the West. Chinese semiconductor companies are developing process technologies

Exhibit 3

Leading-edge nodes are only a small share of foundry volume.

Total foundry capacity per node,
300mm equivalent KWPM[1]



[1]Thousands of wafers per month.
[2]Estimated.

Source: Gartner, converted from 200mm to 300mm scale with 8" equivalent to 2.25

more quickly. SMIC has now achieved the same two-year development cycles as industry leaders. Even though the company may be at a disadvantage due to Western export controls, it achieved stable output at the 65-nanometer level in 2010 and is ramping up additional capacity in 2011. And SMIC's 65-nanometer fabs are running at 95 percent capacity, indicating that there is intense local demand for these chips.

So the emergence of a local market and the apparently limited effect of Western export controls mean that the first two barriers to a significant Chinese presence in all segments of the semiconductor industry are coming down.

The third barrier is also falling, because clusters of excellence are finally coming together in China. Several cities, including Shenzhen, Chengdu, and Dalian, have developed expertise in the local workforce, reached a critical mass in number of fabs, and connected with relevant suppliers nearby. A sure sign of this evolution is that Texas Instruments and Freescale Semiconductor have both opened manufacturing plants in Chengdu, and Intel has set up a $2.5 billion 90-nanometer fab in Dalian.

Looking ahead to the coming decade, it is important to note that China has the world's most compre-hensive, well-funded, and ambitious technology-industry policy, and the semiconductor sector is 1 of the 16 sectors into which stakeholders want to make significant inroads. The country's industrial policies for semiconductors are already beginning to show results as domestic end-to-end value chains emerge: for example, in wireless-communications semiconductors, an end-to-end value chain has developed among SMIC, HiSilicon, Huawei, China Mobile, China Unicom, and China Telecom. Similarly, in wireless systems on a chip, the domestic value chain consists of Taiwan Semiconductor Manufacturing Company (TSMC), Spreadtrum, Huawei, Tianyu, China Mobile, China Unicom, and local consumers.

With three of the four barriers weakening, the lack of intellectual property and know-how is the only significant barrier remaining. While the Chinese have found many ways to acquire the intellectual property needed to establish domestic industries, challenges related to complexity and materials science in semiconductors are more burdensome than in other fields. Acquiring intellectual property and know-how will thus be crucial for Chinese players as long as the semiconductor sector remains a priority industry for government development programs. It should be noted that China has made multiple attempts to entice foreign players to transfer technology, for example, licensing Geode microprocessor-design technology from AMD.

What does this mean for a strategic China engagement model?

As the Chinese government increases efforts to develop the industry, it will likely offer more promising incentives for semiconductor companies to do business in China. This creates a dilemma: it will be difficult for foreign companies to compete from outside the country as their competitors establish beachheads there, but at the same time, the Chinese endgame is clearly the transfer of intellectual property and know-how to allow Chinese companies to compete globally—that is, not just to compete for the emerging local market currently owned by Western players, but to turn around and challenge Western players on their own turf.

A similar scenario played out in the mid- to late 2000s, when the Chinese government launched a major policy initiative to promote the high-speed-rail industry. Seeing a $50 billion market, many foreign players, including Kawasaki, Siemens, Bombardier, and other companies, expressed interest. In 2004, several joint ventures were set up between foreign and local rail companies. While Siemens refused to transfer intellectual property to its joint-venture partner without adequate compensation, Kawasaki and one other player agreed to transfer significant intellectual property to their respective partners on less demanding terms.

As classic game theory would predict, had all three players sold into China on similar terms, the $5.2 billion in potential reward would have been divided among the three equally ($1.7 billion for each, as seen in the top-left box in Exhibit 4). Since, however, Kawasaki and one other player agreed to Chinese terms on intellectual property but Siemens did not, it seemed likely that the two companies that shared IP would split the market equally. But Siemens felt it had little choice but to set up a joint venture including intellectual-property transfer to claim its share of revenues, so another scenario from the initial game-theory projection played out: each of the three players divided their share of the $5.2 billion market equally, and then split that amount with their Chinese partners.

However, at the three-year mark, all the local joint-venture partners, having carefully incorporated key intellectual property from the foreign players, began launching independent products. Since 2007, these products have attracted $20 billion in orders from various state-owned enterprises; foreign players have not won any orders at all.

This cautionary tale is not presented as definitive proof that the joint-venture structure is flawed irremediably. Rather, we mean to suggest that other structures must be energetically reviewed; companies should consider options that do not include the transfer of intellectual property.

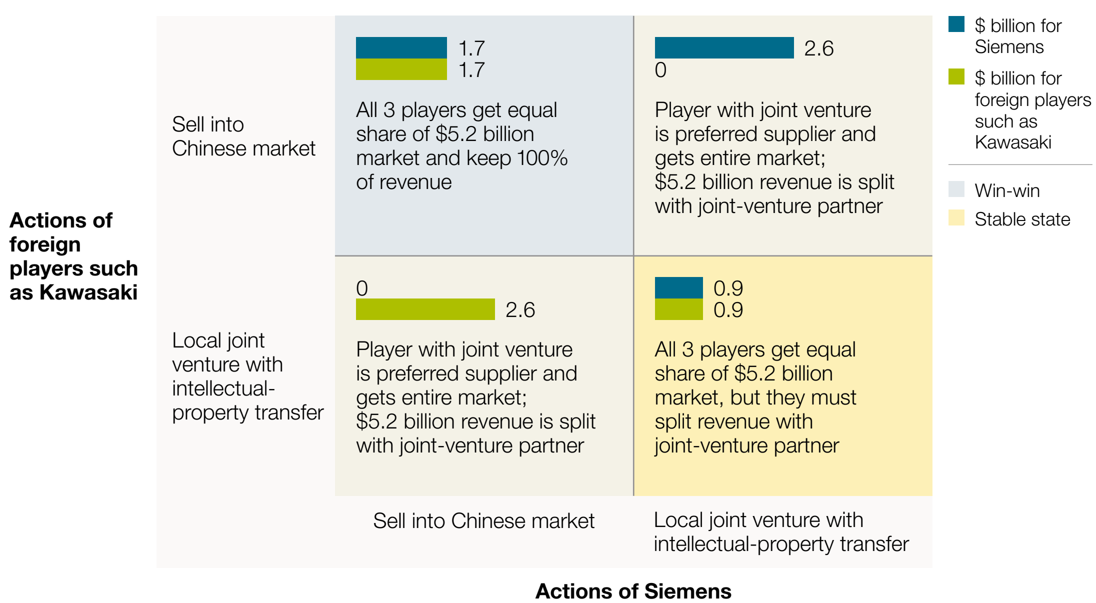
For instance, a number of leading multinational companies have adopted an "innovate with China" approach, which consists of launching R&D centers in China that focus on developing technologies for the Chinese market. General Electric, for example, established a China R&D center that focuses on developing products in line with local market demand and stated government priorities, such as rural health care and sustainable development. Siemens has a similar center working on LED lighting products and low-cost medical equipment. Each product from these centers is tailored to the Chinese market and could potentially be sold in other developing

Exhibit 4

Classic game theory can be used to predict potential outcomes of partnerships in Chinese high-speed rail.

Once Kawasaki and another foreign player agreed to joint ventures, Siemens had to do so as well

Potential rewards, 2004–06: total orders of $5.2 billion

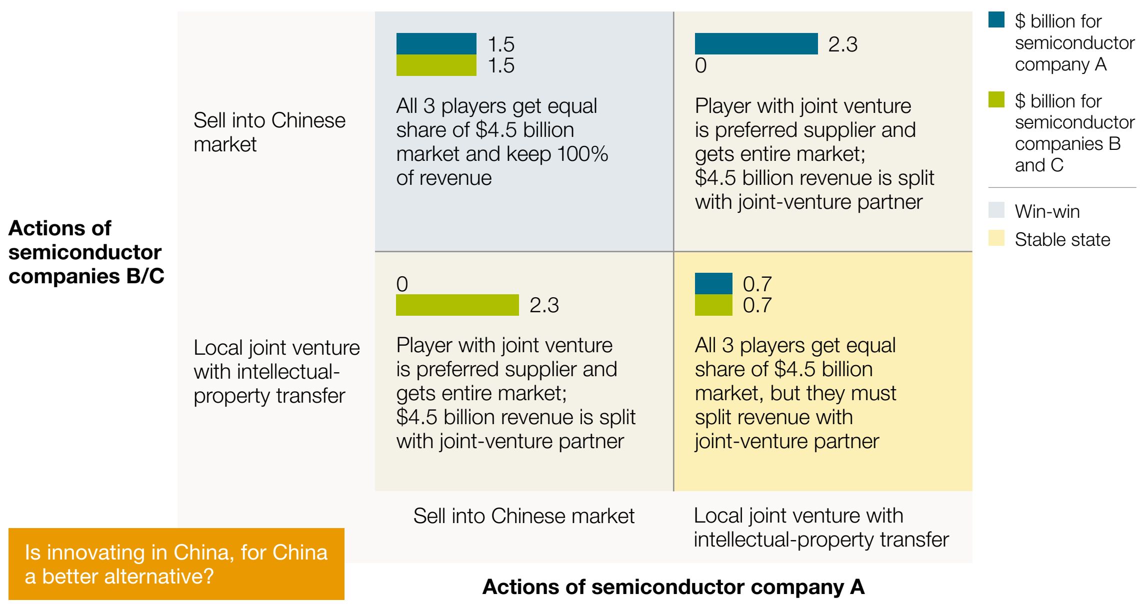


Source: *New York Times*; *Financial Times*

Exhibit 5

Reviewing joint-venture structures can help avoid the prisoner's dilemma, as in this electric-vehicles scenario.

Potential rewards, 2015–20: total potential orders of $4.5 billion[1]



[1]The Chinese government set a goal of 5 million electric cars in China by 2020; $900 in semiconductor content per hybrid or electric car.

Source: *New York Times*; *Financial Times*

markets. This approach serves to limit the exposure to intellectual-property risks to technologies or products developed in China (Exhibit 5).

More broadly, there are a few simple steps that foreign players can take to boost their chances of success in the Chinese market. Keys include developing a go-to-market approach that addresses the problems of Chinese customers, nurturing strong relationships with large state-owned enterprises, and presenting an innovative in-channel model to take advantage of unique characteristics of the market.

Four strategic questions to consider

Until now, foreign players have focused on protecting their intellectual property and know-how by selling finished chips into China.
One common tactical approach is known as price customization; companies offer special product numbers and packaging, and although product performance is slightly lower, the goods cost less. While this approach meets basic market requirements, it creates an opportunity for local players; they can add features and differentiate themselves significantly. To head off that threat, many foreign semiconductor players

Indigenous innovation and next-generation markets for semiconductors

A combination of policies designed to enable large, next-generation end-use markets for semiconductors, together with procurement policies meant to drive indigenous innovation, is likely to create a strategic dilemma for semiconductor companies looking to sell into China.

China has launched ambitious policy initiatives to develop large domestic markets for specific next-generation technologies: cloud computing, the "Internet of Things," and hybrid and electric vehicles. These three markets combined represent tens of billions of dollars of market opportunity in China for semiconductor companies.

The Chinese government is also increasingly emphasizing indigenous innovation in government procurement programs in order to reduce the country's dependence on foreign technology. In November 2009, several Chinese government agencies announced six categories of products that would be directly affected: computer and application devices, communication products (thought to include mobile phones), modernized office equipment, software, "new energy and equipment," and energy-efficient products. China's 12th five-year plan also reinforces the drive to promote domestic innovation in these areas.

Taken together, these policies and a number of stimulus programs may have significant implications for the semiconductor industry. These next-generation technologies and categories of products are expected to be growth drivers for Western semiconductor players in the decade ahead. There is a real potential for Chinese companies to emerge in these areas, as current players have not established clear leadership positions in these applications.

China has not yet tied the indigenous-innovation policy to its policies for these next-generation markets. But there is a real possibility that it will. And any move in that direction would create a strategic dilemma for semiconductor players, which are, frankly, counting on driving significant future growth from these three areas (exhibit).

Simply responding to the challenge of establishing a presence in these areas by creating individual initiatives will not be sufficient. This is a matter that should rise to the highest strategic level for any company that wishes to be a player in these markets. A good place to start would be to understand the implications of potential government and competitor moves, and to develop a response that will accommodate each.

Exhibit

The semiconductor industry may face challenges related to intellectual property for next-generation applications.

The indigenous-innovation policy . . .

- **An "indigenous innovation catalog" of domestically developed technologies was created:** approved products are to be given preferential treatment in state procurement
- **Initial focus areas include 6 high-tech industries:** targets include computing, networking, and energy efficiency
- **The goal is to move from "made in China" to "innovated in China":** the country wants to reduce its dependence on foreign technology to 30% from its current level of 50%

. . . could have significant implications when applied to large, next-generation markets

- **Cloud computing**
  - Policy initiative launched in 2010
  - Trials will take place in 5 cities
  - Key goals include developing core technologies and formulating standards
- **"Internet of Things"**
  - Policy initiative launched in 2011
  - The goal is to develop domestic leaders in the industrial value chain
  - Stakeholders also seek to provide support to develop standards
- **Hybrid and electric vehicles**
  - Policy initiative launched in 2010
  - The aim is to make China a leader by 2020
  - The country seeks to develop 2–3 companies as global leaders in key technology areas

This may result in a strategic dilemma for the semiconductor industry

have begun designing products for China, in China, yet they remain wary of the risks of transferring intellectual property and know-how.

From a strategic perspective, there are four key questions that semiconductor companies must answer to successfully address the opportunity in the Chinese market.

The first question concerns the engagement strategy for intellectual property and know-how. Simply put, what is the best way to use intellectual property in China? Two common strategies are to sell into China while keeping intellectual property in-house and to launch a joint venture with an agreed-upon transfer of intellectual property. However, several other options exist. Companies could launch indigenous development centers in China, which will develop key technologies for the unproven, next-generation markets likely to take off should they become widely adopted in China. Another option is for companies to partner with local downstream players, such as automobile manufacturers or even financial investors. The right way to frame this strategy is at the individual product-line level, not the business-unit or company level. A robust China strategy may include a number of different approaches used throughout the product portfolio.

After determining a strategy, semiconductor players can derive a proper operating model. A carefully crafted operational strategy will focus primarily on competitive activity, a proper understanding of the level of capital investment required, and active government relations. The Chinese government is not monolithic; there are national, provincial, and local stakeholders with whom to negotiate and build longer-term relationships. Managing those relationships is crucial in accessing government contracts and the Chinese market at large.

A third key question involves assessing the impact of the competitive environment (as regards both Chinese and foreign players) on a company's overall China strategy. A competitor selling finished chips into the Chinese market will face circumstances that differ from one investing in local R&D capacity or transferring intellectual property and know-how to a local partner. Might a Chinese player pursue intellectual property and know-how by acquiring a weaker competitor? What role, if any, will the Japanese play in the competitive situation? War-gaming the scenarios can help companies make necessary adjustments.

The last important question involves asking how a company's short- and medium-term strategy will differ from its long-term strategy in the country. Certain tactical choices may be right in a 6- to 12-month time frame, but priorities are likely to shift over a number of years. If the goal is to establish a large local R&D presence from the outset, for instance, it may be valuable to adopt a long-term view from the very first day. Smaller commitments will call for different strategic approaches.

• • •

Over the next five years, cloud computing, the Internet of Things, and electric vehicles are likely to be three of the strongest pools of growth for the global semiconductor industry. The Chinese government has launched a slate of initiatives aimed at developing those markets. As a result, China represents an increasingly important market for global semiconductor companies. However, the comprehensive policies of the Chinese government also indicate that the country intends to develop players who will compete in the top tier of the semiconductor industry.

Three of the four barriers to China's ability to compete are weakening, and the country is ramping up innovation in trailing-edge technology. Western semiconductor companies must determine their strategic posture now. A careful intellectual-property strategy and an operational strategy closely aligned with it will be necessary to develop and hold on to key intellectual property—and thus prosper alongside Chinese players in the increasingly competitive global market for semiconductors. ○

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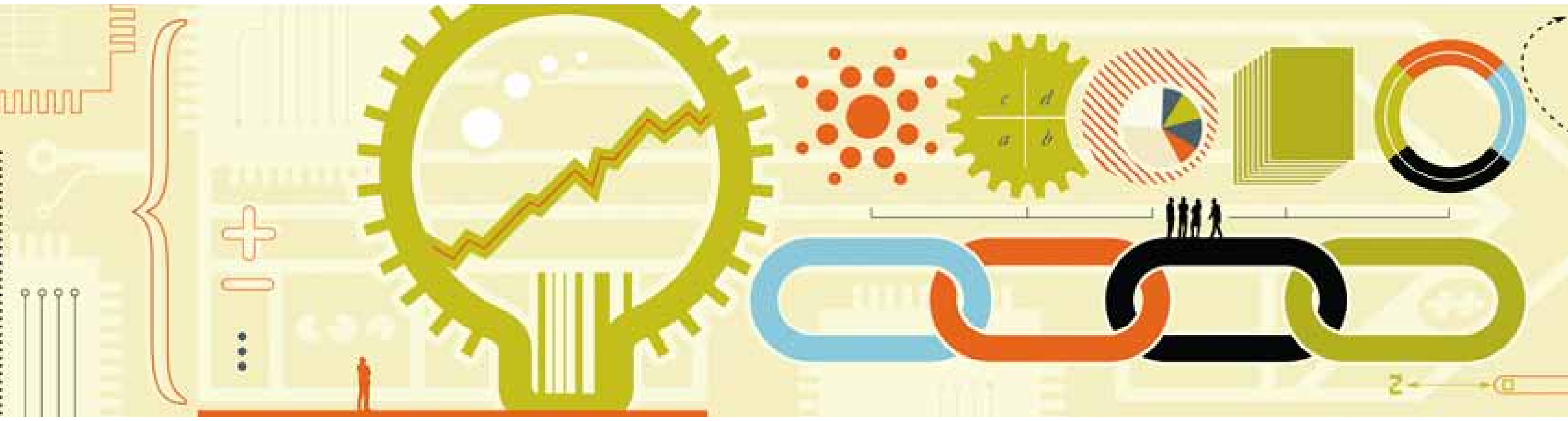


The evolution of business models in a disrupted value chain

The progress predicted by Moore's Law has slowed in recent years. Players across the semiconductor value chain must adjust their approaches to compete as the industry continues to evolve.

Ulrich Naeher, Sakae Suzuki, and Bill Wiseman

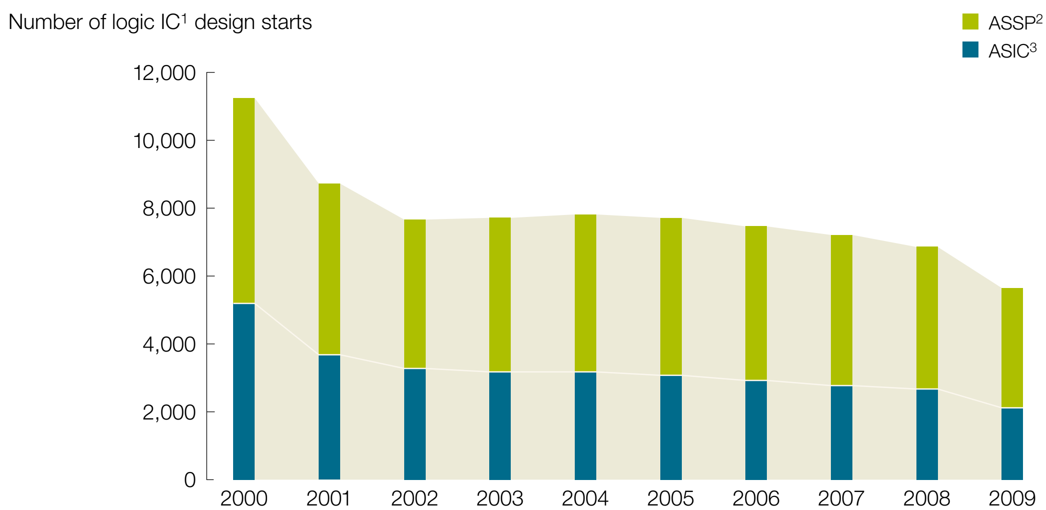
Over the past decade, the growing importance of specialization and scale in semiconductors has led to a breakup of the value chain and the establishment of a "winner takes all" dynamic in many market segments, as noted in "Creating value in the semiconductor industry" (p. 5). Scale has become essential, as technical evolution in line with Moore's Law requires larger and larger investments in R&D each year. Specifically, the pursuit of smaller gate sizes, larger wafers, and competitive scale has resulted in an increase of about 20 percent in investment per year in leading-edge technology nodes. As a result, only a handful of companies—such as Intel, Samsung, and Taiwan Semiconductor Manufacturing Company (TSMC)—can keep up in the technology race.

Design costs, measured on a project basis, have exploded as well, resulting in a reduction of new designs (Exhibit 1). It is no surprise that Intel stands out as the winner in microprocessor units (MPUs), Texas Instruments in diversified integrated device manufacturers (IDMs), and TSMC in foundry; Samsung and Toshiba are arguably the winners in memory. All other players, including most IDMs, net out with either zero or negative cumulative economic profits from 1996 to 2009. Across the industry, semiconductor players destroyed a combined $140 billion in value.

However, not every segment conforms to this Darwinian model; fabless players and segments

Exhibit 1

There are fewer design starts, particularly on newer advanced technology.



[1]Integrated circuit.
[2]Application-specific standard product.
[3]Application-specific integrated circuit.

Source: Global Semiconductor Alliance; Morgan Stanley; McKinsey analysis

such as analog IDMs are two examples of businesses that are less ruthlessly competitive. In fact, the progress predicted by Moore's Law has slowed in many segments of the semiconductor industry. Given this context, we examined ways in which the semiconductor value chain might evolve and explored how current players might adapt in order to compete.

We begin by looking at the changes occurring in the fabless segment. Next, we turn to front-end fabrication, the segment that drove the technical developments that enabled the kind of advances predicted by Moore's Law. Finally, we address back-end fabrication, where the miniaturization race seems to be shifting the assembly-and-test segment.

Fabless design: Players adopt a range of successful models

Over the last decade, fabless players have continued to gain ground, outpacing IDMs and claiming more than 20 percent of the market. Despite some scale in high-end design, there is no overarching winner-takes-all dynamic in this corner of the industry. In fact, as noted in "Creating value in the semiconductor industry" (p. 5), there are far more fabless companies generating economic profits than there are profit-generating companies in manufacturing-related business domains. At first glance, one might conclude that fabless players create value because they require less capital investment. However, we find these companies win by establishing dominance in specific applications rather than across applications. Overall, three distinct business models have succeeded in the fabless space: innovators, fast followers, and mature-market attackers.

The innovator model is exemplified by leading players such as Qualcomm. These companies invest in continuous innovation for new applications, and they constantly expand their core intellectual property. Their efforts focus on unmet needs in the marketplace that come with large potential demand, and their explicit aim is to provide targeted semiconductors at the scale required to recoup R&D costs.

But being first to the market is not a must for fabless players. Broadcom is a good example of a fast follower. Instead of gambling on untested market potential, fast followers pick large, rapidly growing markets and quickly develop intellectual property to enter certain segments. They position themselves as presenting an integrated solution that is a lower-cost alternative to the market leader, with a streamlined business structure.

The third model, the mature-market attacker, is best illustrated by MediaTek. It may appear quite similar to a fast follower at first glance. However, such companies wait until an application area has reached significant global volume before entering the fray. At that point, they attack the market with a simplified value-for-money product offering. Execution excellence—that is, efficient development and speedy production—is crucial for these players. Other companies in this category include Monolithic Power Systems, Richtek Technology, MStar Semiconductor, and RDA Microelectronics.

With the ongoing commoditization of manufacturing services and better access to leading-edge intellectual property, the fabless industry will profit from its focused business system. We expect these players to dominate more and more successful applications, especially in consumer electronics and some areas of IT. IDMs and even established microcontroller and microprocessor players will continue to cede ground to fabless competitors. The compound annual growth rate of the fabless segment, which currently outperforms the overall semiconductor industry by more than 5 percentage points a year, seems sustainable over the longer term.

A more interesting model that may be reemerging is that of the integrated original-equipment manufacturer (OEM). In the past 30 years, many OEMs, such as Motorola and Hewlett-Packard, divested their semiconductor arms due to the high capital intensity of these businesses and the need for scale. Today, a new generation of OEMs that are tied neither to in-house process technologies nor to software development are taking more ownership of integrated-circuit design. Apple and Google may indicate the emergence of a larger trend, in which we see that the intellectual property for functional design may not belong fully to the chip maker but to a new kind of integrated OEM. With valuable functional designs in hand, such players may in-source or outsource chip design based on cost. Companies such as Apple and Google have sufficient scale and capability to become fabless for both the box and the chips. Because these OEMs tend to be market leaders, they can compete with innovator and fast-follower companies for share in the overall profit pool. Of course, OEMs without the scale or skills will continue to rely on mature-market attackers to sustain their businesses.

Front-end manufacturing: What are the limits of vertical disintegration?

Over the past several years, many semiconductor companies have decided to go "fab lite," or step out of some aspects of the capital-intensive, leading-edge front-end technology-development and fabrication part of the value chain. Nearly all IDMs have outsourced some of their production to foundries. Even the Japanese, who are known for their reluctance to give up in-house capabilities, are going asset light, at least in part. Examples include Fujitsu, Renesas Electronics, and Toshiba. As a result, the foundry business has surged over the last decade, outperforming IDMs by an average of about 5 percentage points each year (Exhibit 2).

In the longer term, the foundry business has evolved over the last 20 years. Although it earlier competed on factor cost advantages, productivity gains, and operational excellence, it now depends on true technology leadership, scale advantages, and a superior ecosystem for product design. Modern foundries can provide every type of support: for example, developing intellectual property, offering photomasks, and offering access to networks of third-party design centers. Services even include competence in testing and packaging. More recently, foundries have started to offer 3D expertise, interposers, and back-end integration as a means of differentiating themselves from competitors.

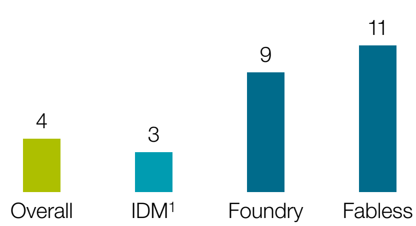
As noted above, in the early days, the foundry model generated profits primarily through low costs. Analysis of manufacturing costs that pitted European IDMs against Taiwanese foundries in the 1990s indicated that the cost advantages of the foundries were close to 50 percent. By the mid-2000s, leading foundries' process technology reached parity with other leading-edge players in standard complementary-metal-oxide-semiconductor (CMOS) technologies. By the end of the 2000s, foundries became the core of new technology clusters. They no longer had to compete on price.

Despite the fanfare, foundry volumes occupy only 20 percent of current manufacturing capacity

Exhibit 2

Fabless and foundry businesses have grown above the industry average, whereas IDMs have grown below it.

Revenue growth by value-chain slices,
% compound annual growth rate, 2005–10

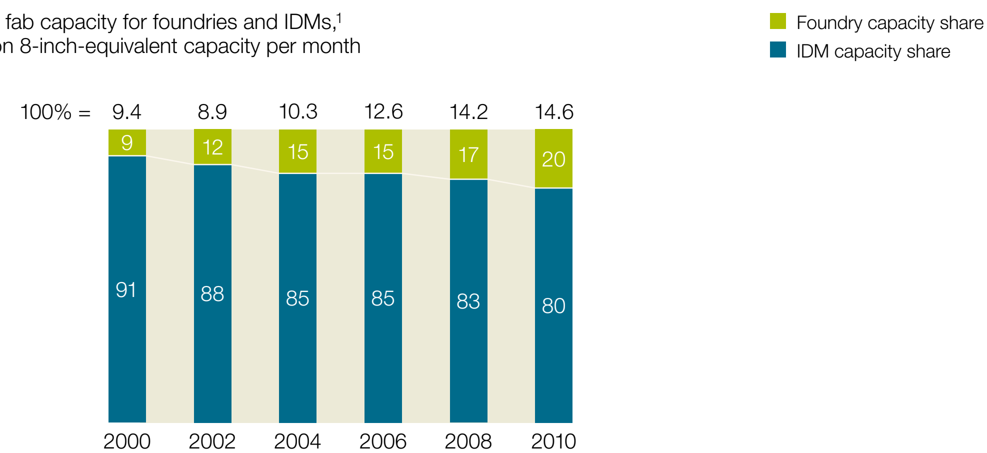


[1] Integrated device manufacturer.
Source: iSuppli; IC Insights; Gartner

Exhibit 3

Despite early fanfare, foundry volumes remain low relative to IDMs.

Semiconductor fab capacity for foundries and IDMs,[1]
%, total in million 8-inch-equivalent capacity per month



[1] Integrated device manufacturers.
Source: iSuppli, Q4 2010; World Semiconductor Trade Statistics, Q4 2010; McKinsey analysis

(Exhibit 3). With the expertise that many foundries currently possess, when will this business model truly take off? The reality is that there probably will not be any great jump in market share.

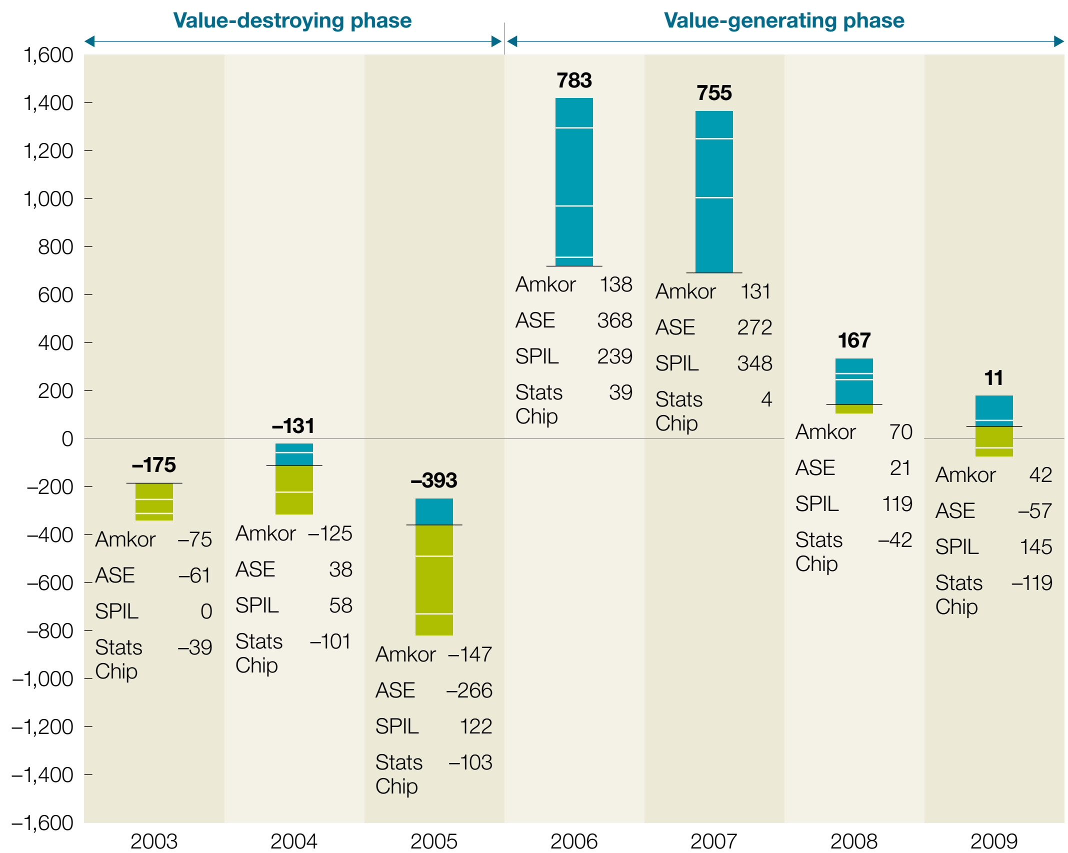
Growth in the foundry business has rested on three pillars: first, leading-edge fabless companies such as Qualcomm and Nvidia rely on foundries to produce their designs, including hot products such as application-specific integrated circuits (ASICs) and application-specific standard products (ASSPs), all of which are sold into the global semiconductor market. A second pillar of growth has come as a result of IDMs looking to go fab lite; examples include NXP, Texas Instruments, Freescale, Fujitsu, and Renesas. The third growth driver has been increasing share among existing customers due to foundries' ability to produce chips for cutting-edge and trailing products at a lower cost.

In our market model, we expect most new ASIC or ASSP capacity to be built within the foundry ecosystem. In addition, all the new leading-edge capacity for nonmemory applications will end up at foundries or Intel. Nevertheless, we assume it will be difficult for foundries to gain share at the lagging edge of the chip market because IDMs are producing them based on sunk-cost economic models. It will be equally challenging for them to move in on the specialty technology businesses of IDMs, which also thrive due to depreciated assets (and which display relatively low portability across fabs precisely because of the level of specialization in these products). Given these assumptions, the slowdown of Moore's Law node migration and the fact that most IDMs have already turned asset light will impede foundry growth. In total, we expect the segment to grow 5 to 10 percent a year, rather than the 10 to 15 percent it grew in years past.

Exhibit 4

Four leading OSAT players adjusted their business models and are generating economic profits.

Economic-profit generation[1] for the top 4 OSAT[2] players, $ billion



[1] Calculated as (return on invested capital – weighted average cost of capital) × invested capital.
[2] Outsourced semiconductor assembly and test; the 4 players referenced in the chart are Amkor Technology (Amkor), STATS ChipPAC (Stats Chip), Siliconware Precision Industries Co. Ltd. (SPIL), and ASE Global (ASE).

Source: McKinsey Corporate Performance Analysis Tool

While foundry demand may be growing less quickly, a great deal of capacity is coming online. As a consequence, we expect leading foundry players such as TSMC, Samsung, Global Foundries, and United Microelectronics Corporation to compete for customers more aggressively than they have in the past, as capital expenditure and process-technology development costs skyrocket. Second-tier players from China and Malaysia will also try to operate at capacity. In addition, Japanese IDMs might give away surplus capacity to potential customers at "cash cost," hurting the foundries' price points. All in all, price competition in this sector will likely intensify.

More recently, the earthquake and tsunami in Japan brought the need for supply-chain diversification to the forefront. Specialization and geographic concentration, which helped drive success in foundries in the past, are now becoming risks. Will foundry companies be able to provide risk diversification from natural or man-made disasters? Will OEMs be willing to bear the infrastructure costs associated with having multiple suppliers on fragmented campuses manufacturing interchangeable and commoditized technologies? The answers to these questions are unclear at this time. However, continued business-model innovation is needed to enable multisourcing with minimal cost impact, if not further cost reduction. If this evolution can be achieved, it will likely drive continued disintegration in the semiconductor value chain.

All in all, it does not look as if the foundries' current 20 percent market share will grow appreciably anytime soon. Indeed, in addition to interfoundry competition, these players are quite likely to face competition from other players along the value chain such as Intel and Samsung.

Given these facts, and the implications of deceleration with regard to Moore's Law, how will foundries capture a fair, if not disproportionate, share of the profit pool? From the other side, how will customers capture more value from the foundries? Naturally, the big foundries would favor fewer foundry players. At the same time, OEMs, IDMs, and fabless players would prefer to have multiple leading-edge foundries. Investment for capacity, partnerships, alliances, and distribution of orders across foundries over the next three to five years will be crucial in determining the competitive dynamics of the industry.

Back-end manufacturing:

The race for miniaturization brings success to OSAT players

Chip packaging has shifted to an outsourcing model more quickly and more extensively than front-end processes have. In fact, many expect that the outsourced share of this segment could reach 50 percent of the market by 2013.

In the not-too-distant past, outsourced semiconductor assembly and test (OSAT) companies were regarded as low-end, commoditized service businesses, and the competitive dynamics of the business were driven by price competition. This had a negative impact on the economics of the industry. Between 1996 and 2006, the sector, cumulatively, delivered no significant economic profit. However, the same analysis for the next three years shows a very different result (Exhibit 4). Part of the OSAT industry has undergone a transformation, and there are now two profitable subsegments: the very profitable high-end players and the less successful mainstream OSAT players.

As the pace of innovation slows in the front-end segment of the semiconductor market, the pressure on back-end companies is increasing; these players are expected to offer sophistication and technical differentiation in a bid to increase chip performance. Technological differentiation will continue to drive the two-tier market structure: there will be oligopolistic high-end players and commoditized mainstream players. The OSAT industry can stay profitable at the high end as long as the top players have the technical skills required to differentiate the degree to which the chips they receive from foundries can be tuned to the needs of different products—and if they are able to avoid price wars.

Four leading OSAT players have redefined their businesses models successfully and are generating economic profits. Amkor Technology, STATS ChipPAC, Siliconware Precision Industries Co. Ltd., and ASE Global are the four high-end OSAT companies, and each has significantly improved its profitability since 2006, leaving aside some turmoil caused by the Lehman Brothers collapse and resulting economic downturn.

These companies successfully migrated from value destruction to value creation by focusing on improved capital productivity through careful management of investments and by introducing more sophisticated pricing models. Furthermore, they invested in advanced packaging technologies and improved miniaturization technologies, such as ball grid array (BGA) and flip-chip BGA, and shifted their product portfolio to those categories. The top four OSAT companies account for 80 to 90 percent of all outsourced substrate-based packaging services (Exhibit 5). On the other hand, lead-frame packaging services have become essentially a commoditized market. Technology-based differentiation allows certain players to access more specialized markets. In those narrower niches, pricing pressures are much lower than they are in the more commoditized packaging segments. Companies thus want to be in the substrate rather than the lead-frame packaging-services game.

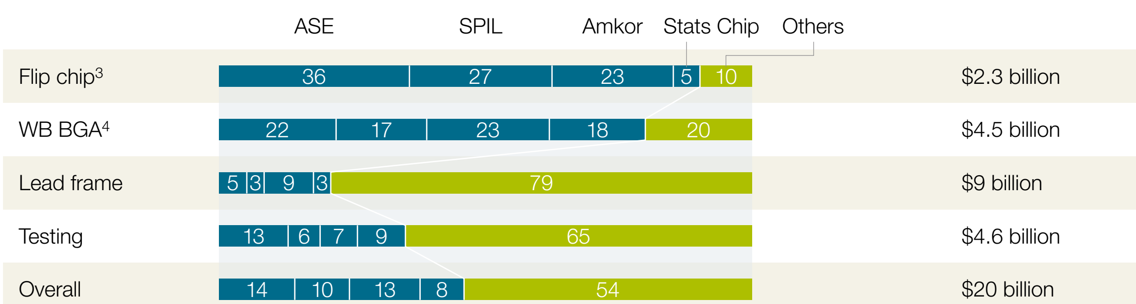
These four companies avoided the vicious price competition of the early 2000s, and they also improved their cost position, reducing capital expenditure by planning capacity more carefully and by avoiding unnecessary capacity buildup. One way they have done this is by maintaining leadership in technology,

Exhibit 5

Revenues can be broken down by package type.

OSAT[1] revenue split (among top 4) by package type,[2]
%, FY 2008

Top 4 players



[1] Outsourced semiconductor assembly and test; the 4 players referenced in the chart are Amkor Technology (Amkor), STATS ChipPAC (Stats Chip), Siliconware Precision Industries Co. Ltd. (SPIL), and ASE Global (ASE).
[2] Figures may not add up to 100% because of rounding.
[3] Includes bumping.
[4] Wire-bonded ball grid array.

Source: Company filings; expert interviews; McKinsey analysis which has allowed them to establish equipment-consignment agreements with key accounts, thus avoiding overproduction and reducing the need for capital investment.

As the technology race shifts to OSAT players, the industry will find itself at a turning point. For the leading high-end OSAT players, the lifeline has been the industry's increasing need to package smaller, advanced-node chips. Will those leading-edge players be able to break away and maintain a comfortable and profitable oligopoly? Or will mainstream players also enter the advanced-packaging technology race, creating price competition that will likely take value away from the current players in the OSAT sector? The deciding factor may be the advantage that accrues to companies that lock in the limited external resources that allow them to maintain differentiability or to play catch-up. Those limited resources might include capital investment from leading-edge foundries seeking to provide integrated solutions, or the advanced-packaging technologies held by players in high-cost countries, such as the Japanese IDMs.

• • •

The deceleration in progress along Moore's Law has changed the rules—from a strong and almost sole focus on process-technology development to a more diverse set of success factors, such as additional value-added services, operational performance and responsiveness, intellectual property, and cost management. This industry, which had represented the essence of advanced technology, is becoming more commoditized, and competition within any given slice of the semiconductor value chain will continue to escalate in the years ahead. The competitive arsenal is expanding to include a number of management skills—such as strategies for mergers and acquisitions—that will help companies battle other players' strengths, securing intellectual property and locking in market share. Operational excellence is yet another imperative. Those that can get the mix right and adjust their business models to the changing landscape will be well positioned to break the boom-and-bust cycle and generate strong economic profits in the years to come. ○

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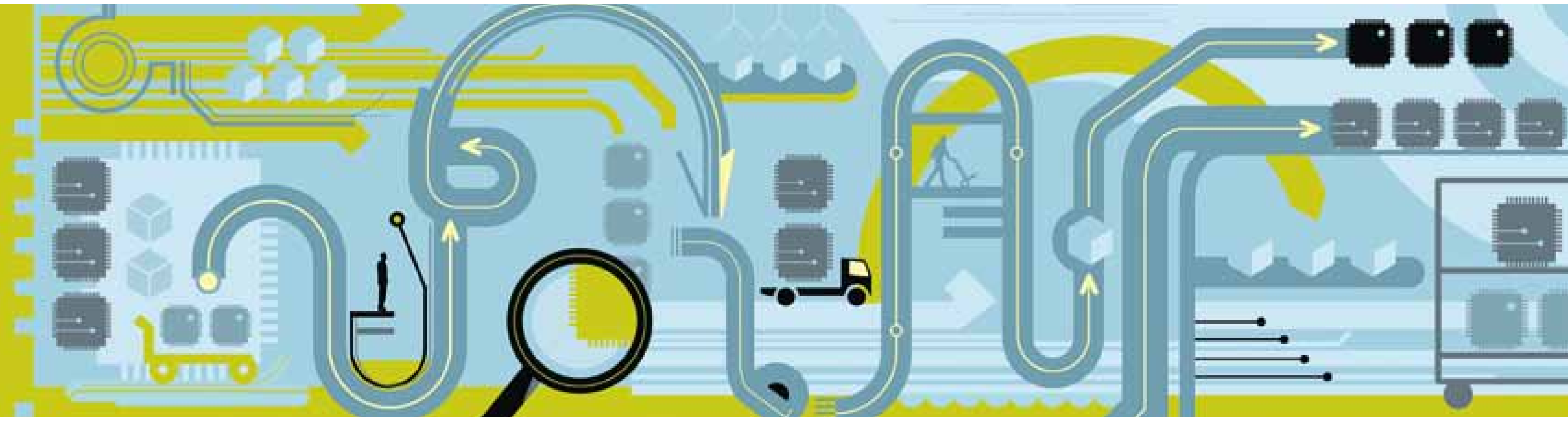


From source to drain:
Fixing the supply chain

Supply-chain excellence has proved elusive for semiconductor players, but a handful of initiatives can yield significant improvement.

Greg Hintz, Sri Kaza, O Sung Kwon, Markus Leopoldseder, and Florian Weig

Connecting the terms "semiconductor," "supply chain," and "excellence" requires courage. Asking a customer of a semiconductor company about its supplier's delivery performance can be a genuinely emotional experience. Of course, this must be put into the context of 2008 to 2010, one of the worst inventory-depletion/demand-surge cycles in economic history. Current microcontroller woes in the automotive industry, following the tragic events in Japan in March 2011, must also be taken into account. Even if we normalize for such events, however, customers' views are generally pretty bleak.

One might say that customers judge the semiconductor industry too harshly. High capital intensity, coupled with long cycle times and a position far down the value chain, make semiconductors a classic case study for supply-chain problems ranging from "pig cycles" to "bullwhip effects." These are tough problems to solve.

In fact, customers are a little sharper-eyed than one might assume. Supply-chain performance levels within the industry vary significantly even within the same applications. Over the last three years, we have built a benchmark database containing 9 of the top 20 semiconductor players. Key metrics like "on-time delivery to customer request date" vary by almost 40 percentage points, while others such as "forecast accuracy on product-family mix, three months out" can vary from levels near

30 percent—equivalent to a random walk—to levels above 90 percent achieved by serious consumer-electronics original-equipment manufacturers (OEMs) and original-design manufacturers (ODMs).

But no single player displays excellence across the board. Some have clearly excelled in bringing down supply-chain costs and inventory. Others have focused on improving service levels. Yet few have found the ideal balance between the two. Hence, we conclude that there is significant upside opportunity for all players in the industry.

We turn first to the value we see in excellent supply chains. To capture this value, we describe commonly observed issues and tried and tested improvement levers to get the fundamentals right. We conclude with our beliefs about the characteristics of truly differentiated semiconductor supply chains in the future.

Value in excellence

The business case for supply-chain excellence is strikingly simple: Exhibit 1 contrasts the customer experience between a low- and a high-performing semiconductor player. Based on insights from our own work on five large semiconductor supply-chain transformations in the last five years, we believe revenue upside is the most underestimated impact of supply-chain improvement. In our experience, the revenue impact from a significant improvement in supply-chain performance can amount to an increase of 5 to 10 percent. In addition, we typically identify reductions of at least 15 percent, and in some cases as much as 30 percent, in inventory and working capital.

Exhibit 1

Taking a semiconductor customer's perspective illustrates the value that high-performing supply chains can add.

Poor semiconductor supply-chain experience (real example)

- You wait 1 week for a response to your order
- Your supplier tells you he cannot meet your requested delivery date for more than half of your orders
- For more than a third of your orders, your supplier misses his promised delivery date; very often he fails to tell you up front
- You have no option for urgent orders; instead, many products you need are out of stock

Where would you buy?

Best-in-class semiconductor supply-chain experience (real example)

- You get a confirmation of your order within 24 hours and are able to track its progress
- Your supplier manages to fulfill your request in 9 out of 10 cases; he even offers differentiated service levels depending on the criticality of your supply
- Your supplier almost never lets you down; in the rare instance when he misses a shipment, he notifies you as soon as possible and discusses mitigation options
- For an extra charge, you are able to place rush orders or get other value-adding services

While excellence in the supply chain has major cash and cost advantages, additional market opportunity is key

A successful transformation also reduces the day-to-day firefighting and tedious manual interventions we encounter in many semiconductor organizations. This does not generally have an enormous impact on cost efficiency, but it is a significant operational improvement, freeing up management time for other things.

Moreover, the business case for supply-chain excellence will become increasingly important. To date, capturing the next wave of innovation and technology advancement promises much more upside than investing in a state-of-the-art supply chain. Our hypothesis is that this will change: as an ever-increasing share of the industry and its products moves away from leading-edge technology, this will allow for innovation in business operations as well.

If successful, a high-performing supply chain can be a competitive weapon: flexible, agile, and reliable.

Why excellence is difficult to achieve

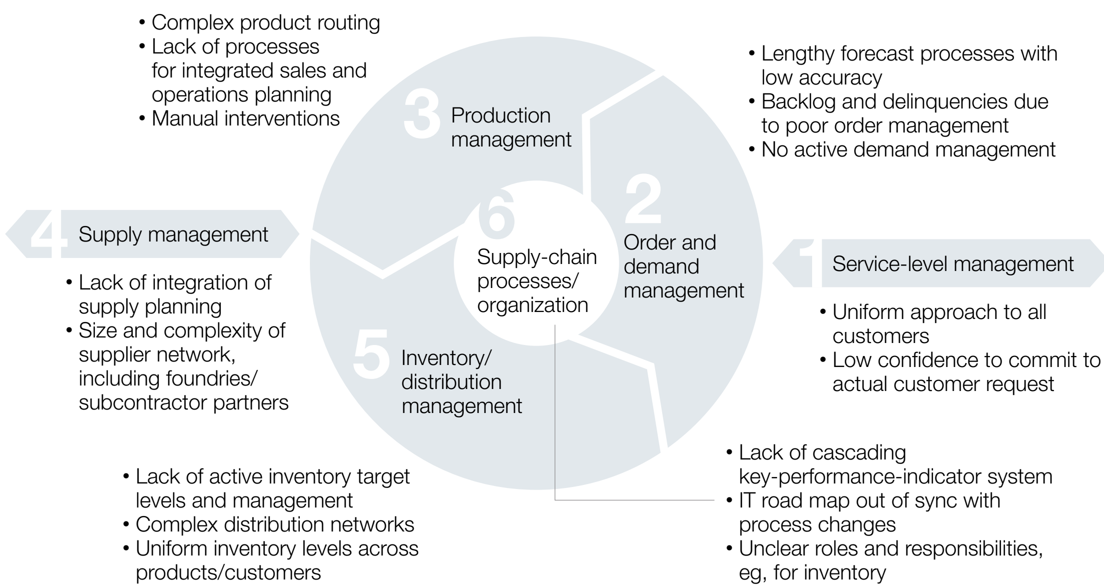
When we analyze supply chains, we do so starting from service-level management, moving to supply management, then to distribution- and inventory-management processes (Exhibit 2). We look at both physical and digital data flows, effectively "stapling ourselves to orders" as they pass through the various systems and from team to team. This complements our quantitative and qualitative benchmarking.

In our recent work, we found that several issues were widespread in the semiconductor industry. The following are some of the most frequent and important issues to address:

Exhibit 2

Many semiconductor companies experience similar issues along the supply chain.

Six links on the supply chain and associated issues



Some of the most important issues in the semiconductor industry include insufficient segmentation of the supply chain, low ability to manage demand, and low forecast accuracy

- Little to no segmentation of the supply chain: all customers, orders, and products are treated equally
- Low ability to manage demand actively, particularly in times of allocation
- Low forecast accuracy due to a lack of collaboration with the customer, inefficient processes, and misaligned incentives
- Insufficient engagement from senior managers and executives, as well as a lack of true decision making related to customer trade-offs; for example, given a constrained supply, should a company sell to Customer X or Customer Y in sales and operations planning (S&OP)
- Complex routing in the production process
- Poor rules about product life-cycle management, leading to aging or obsolete inventories
- Lack of integrated key performance indicators (KPIs) supported by a robust IT infrastructure that enables data visibility and efficient processes (for example, order management)

Some case examples provide more detail on forecasting accuracy: at one client, the forecast process for a quarter finished in the second month of the quarter. What is worse, by the time the forecasting process was complete, the initial inputs were no longer valid. In another case, a client forced its sales team to forecast a detailed product mix four quarters out. A third penalized its sales force for any deviation of forecast from sales targets, leading to end-of-quarter panics as these artificial forecasts had to be supported by frenzied sales activity and discounts. Needless to say, a vicious cycle of mistrust developed in these organizations between production and sales, the former making sure that inventory levels rose to match potential last-minute surprises from the latter.

A lack of integrated KPIs, the final issue on the list, has been a point of contention for our clients. Most of them have upgraded their IT systems by now, introducing complex planning and supply/demand matching tools from i2, SAP, or other vendors and integrating them with complex enterprise-resource-planning systems. Many clients have yet to see a return on what are often significant investments. Sometimes, however, the reasons for that low return are obvious: we frequently find IT systems redesigned with legacy processes, crippling the systems right from the beginning.

Making things better

All too often, actions to improve the supply-chain situation are focused on only one area at a time (for example, fixing forecasting without addressing S&OP). However, given the interdependencies inherent in a supply chain, we recommend an integrated approach to supply-chain transformation. A highly visible cross-functional "war room," in which all information is available and a cross-functional team makes decisions, has proved to be an effective instrument of change. The war room allows for both quick wins and fast reactions if improvements are not developing as projected. It is therefore particularly effective in crisis settings with tight customer allocations or short supplies. It continues to be useful even when the crisis has passed: we have found that many of our clients have maintained the physical location to leverage the convening power and clarity a war room can bring.

Beyond the war room itself, we typically recommend putting in place three to five targeted initiatives to drive change. Here are three examples.

One client started a *forecasting-improvement initiative*. The core insight for the company was that the timing, the frequency, and the granularity of its forecasts were not tied to its decision needs. For example, nine months before delivery, the client had to decide on front-end foundry capacities. Three months before delivery, it had to decide on the product mix to build (that is, how many of which product)—a much more granular level of decision making. The foundry-capacity decision was quarterly; the production plan, weekly. The first required high-level assumptions on the number and technology of wafers needed, and the latter required details on product mix.

The approach the initiative team took was to work backward from the decision meeting, specifying granularity and timing of forecasts. The next question was how and where to get the necessary information in a speedy manner, thereby reducing the latency period between the original input and the decision. By assessing the existing processes in this way, the client arrived at a list of simple rules on improving forecast accuracies (Exhibit 3). The team realized, for example, that only 20 percent of parts were driving 80 percent of the

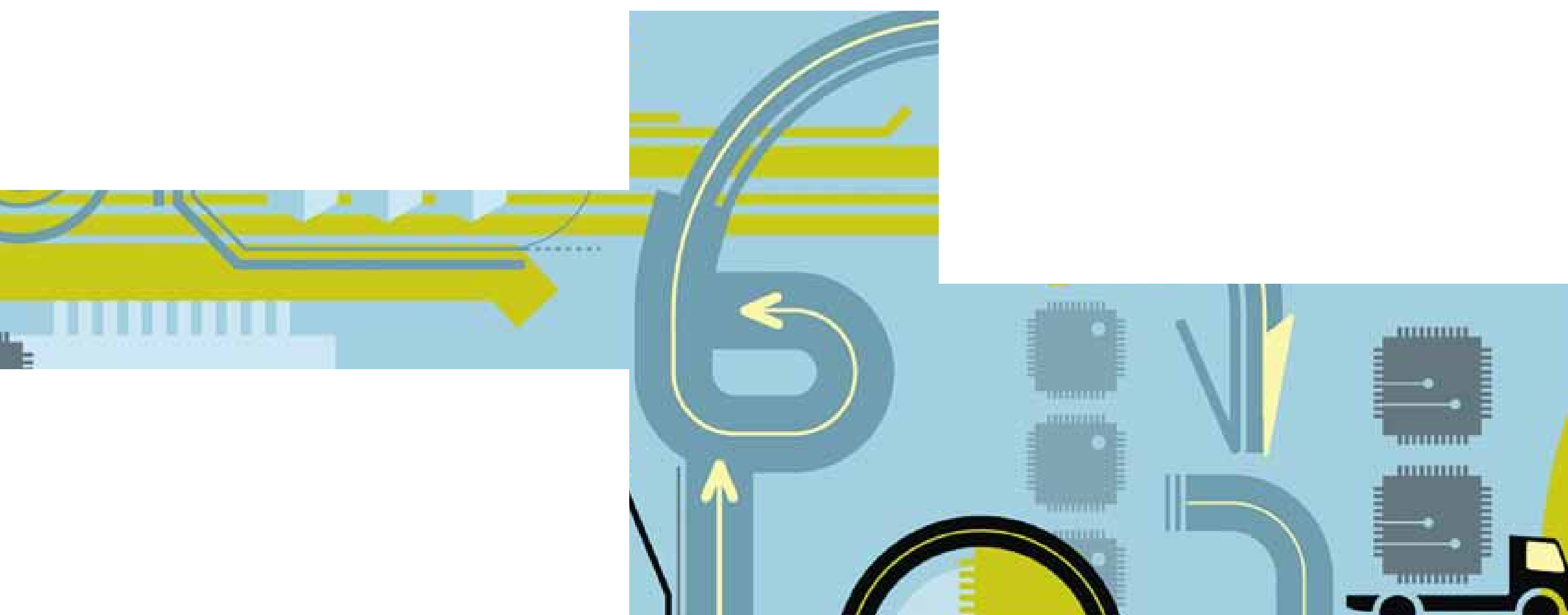
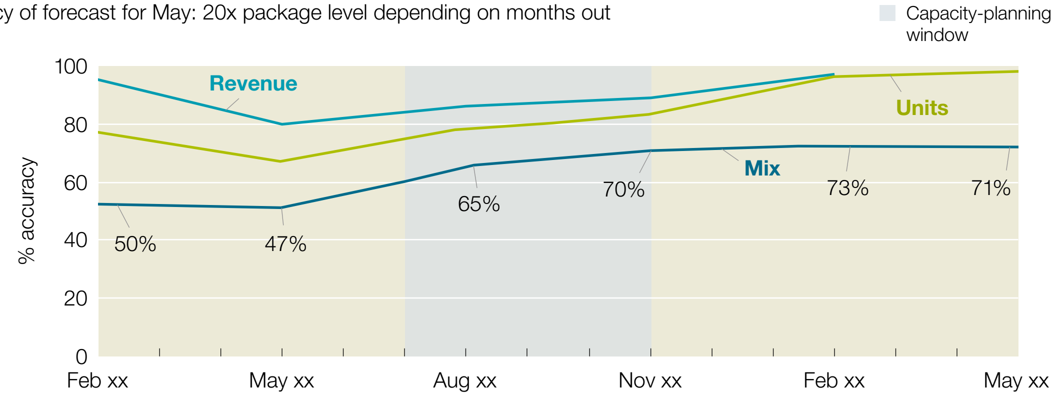


Exhibit 3

Forecast-accuracy measurements must be tied to critical operations decisions.

Accuracy of forecast for May: 20x package level depending on months out



Months out	15	12	9	6	3	0
Decisions to be made	Technology decisions (eg, tech node)	Front-end/ foundry capacity		Back-end capacity	Front-end starts	Back-end starts

Questions:
What are the critical time horizons?
What granularity is needed?
Which cuts are needed?

overall forecast error. This made it possible for the team to focus its sales and marketing people on forecasting the products that truly made the difference. The team also uncovered islands of excellence within the organization: some accounts were operating at significantly better forecast-quality levels than other similar accounts, thereby allowing for the identification and dissemination of best practices. Finally, the client team also realized that tying sales-force incentives to forecast accuracy (for example, awarding compensation based on accuracy rather than size of order) had substantial impact.

Another client revised its inventory management by introducing a *new product segmentation*. It had learned from the diagnostic, which included a segmentation exercise, that slow-moving “C” products accounted for just 5 percent of revenues but made up 20 percent of inventory. The segmentation was conducted on two simple axes: customer lead time and an A-B-C classification of product contribution to gross margin. New inventory strategies were devised to create the following designations: “pull from finished goods,” “pull from die bank” or “build to forecast,” and “build to order” (for rare or long-lead-time products). Simulated implementation of these new strategies showed that the number of days of inventory would decline by 10. The simulated benefits were fully captured within two calendar quarters.

A third client learned about its poor order management through the diagnostic. As much as one-third of its orders were modified within the stated lead time. Processing orders took up to one week and customers were, in many cases, not notified about rescheduled deliveries because manual interventions compromised the reliability of information flow in the system.

One initiative developed was the use of *lean tools to clean up internal interfaces and processes* such as value-stream maps and operator-effectiveness analysis. The team also grouped customers into segments based on historical ordering lead times and levels of order churn. A targeted strategy tied to the behavior of a given customer segment was put in place. Those who did not adhere to the relevant strategy were educated and also faced penalties; for example, fees were introduced to reflect the costs in the client's supply chain that were a result of the client's behavior. Service levels were adopted, and for key customers, lead times were significantly reduced—thus decreasing the probability that a customer would change its mind.

Below are three commonalities of the previously discussed levers and initiatives:

1. They require very little investment. This is often the case, as existing IT and system capabilities frequently significantly exceed the real need for process improvement.

2. Despite the appearance of independence, each initiative really needs the others to be carried out as well if it is to deliver visible impact. As such, the design of a formal program requires a thorough understanding of the entire organization, including both its physical and information flows.

3. Supply-chain transformation is a true cross-functional change-management exercise and therefore needs both top-management attention and alignment across functions. The sheer scale and elaborateness of a modern semiconductor supply chain, with its multiple internal stakeholders and interfaces (for example, those among procurement, manufacturing, planning, product development, marketing, and even sales), require alignment of incentives across these functions.

Outlook: Toward excellence

A semiconductor company that improves its supply chain can certainly excel within the industry and deliver superior performance. At the same time, the improvements discussed so far will eventually become table stakes—necessary to remain a viable competitor but not enough to be truly differentiated. We encourage the industry to look beyond itself and harvest insights from supply-chain champions outside semiconductors. Players in other industries model a number of best practices:

- Aggressive reduction of cycle and transit times at all stages: front end, back end, and distribution

- Postponement of stock-keeping-unit differentiation (for example, delay the marking of otherwise finished goods until a customer order arrives, and only then stamp the chip with customer-specific information)

- Integrated planning and restocking systems between OEMs/ODMs and retailers

- Outsourcing of core supply-chain processes to specialist providers that are encouraged by clear service levels

- Truly differentiated customer-service levels with upgrade options for customers

By focusing on these strategies, a semiconductor company can create a truly differentiated competitive advantage. Furthermore, a company that regularly employs these approaches will become highly appealing to any customer that has had experience dealing with the ups and downs of the semiconductor industry. In this ever-maturing industry, this advantage could prove to be particularly valuable. o

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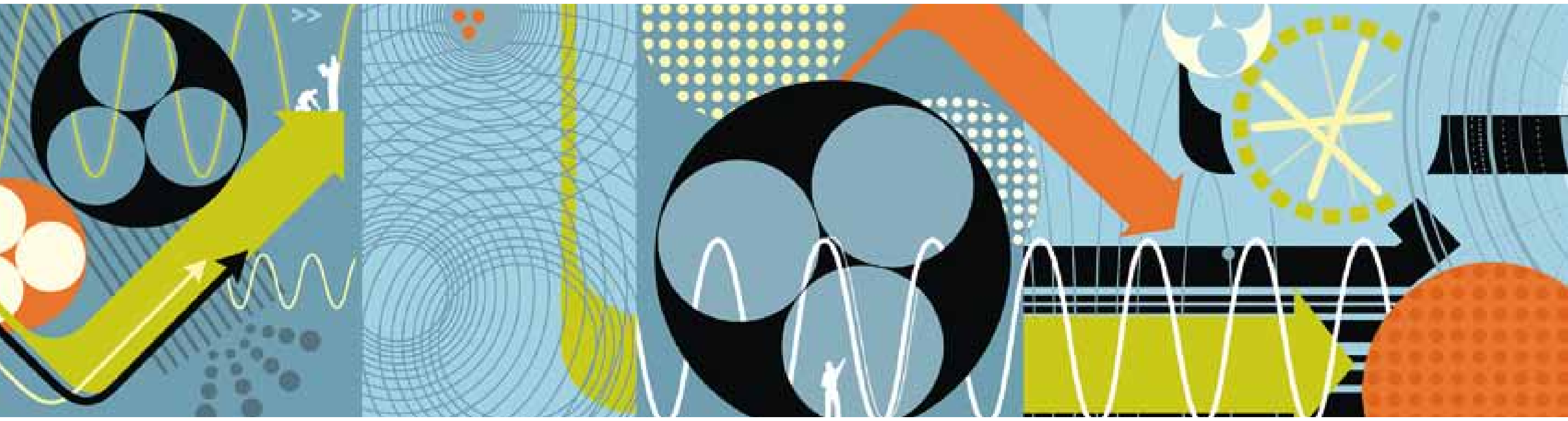


Will analog be as good tomorrow as it was yesterday?

Many worry that 300mm manufacturing capacity will destabilize pricing across the analog semiconductor market. We argue that only a few segments have reason to be concerned.

Abhijit Mahindroo, David Rosensweig, and Bill Wiseman

Within the semiconductor industry, the analog segment has been remarkably profitable and stable in recent years, largely free from the punishing investment demands of Moore's Law that have beset its digital counterpart. Consider the following aspects of analog's recent performance.

Strong growth. Analysts project that the analog segment will grow twice as fast as the overall semiconductor market during the 2010–14 period (8.8 percent versus 4.3 percent compound annual growth rate[1]), primarily because of expected rapid growth in consumer and enterprise wireless devices. Already, the value of analog and mixed-signal content in the Apple iPhone 4 is 50 percent higher than that of the logic content.[2]

Healthy margins. Analog players exhibit gross margins of 40 to 70 percent—generally higher than margins obtained in the digital segment. The higher numbers are possible primarily because lower levels of capital expenditure are required. Other than the microprocessor segment, which is a duopoly, the analog segment has historically created the most value in the semiconductor industry when measured according to economic profit.[3]

Room to play. The heterogeneity of products, process technologies, and applications creates opportunities for various companies and prevents an oligopoly from forming. In 2009, the top 10 players had approximately 50 percent

[1] iSuppli AMFT 3Q 2010.
[2] Logic includes microprocessor, microcontroller, digital-signal processors, and general-purpose logic. iSuppli teardown of the iPhone 4, available at http://www.isuppli.com/Teardowns/News/Pages/iPhone-4-Carries-Bill-of-Materials-of-187-51-According-to-iSuppli.aspx.
[3] Defined as the profit generated over a company's cost of capital, that is, [NOPLAT / (WACC x invested capital)].

market share in the analog segment, compared with 80 percent share for the top 10 in logic and 90 percent in memory.

Stability. Market share for most analog players has remained relatively constant over the last decade. Analog design is an art as much as a science. Design talent remains a barrier to entry, as it takes 5 to 10 years to train strong designers.

The 300mm challenge

The most significant development within the industry over the past 18 months has been the move of several industry players to establish fabrication capacity for 300mm wafers. This development has proceeded from an understanding that a successful transition from 200mm to 300mm wafers could lead to a 20 to 30 percent reduction in front-end-manufacturing costs for analog and mixed-signal products, resulting in a 10 to 15 percent reduction in per-unit die costs. Many are now asking whether the development of 300mm capacity will alter the stability that analog has enjoyed, by triggering a new wave of capital investment as players seek to remain cost competitive. In our view, the effects of the transition to 300mm will be real, but they will be confined to selected segments and not affect the analog industry overall.

In late 2009, Texas Instruments (TI) announced the $172.5 million purchase from bankrupt DRAM-maker Qimonda AG of 300mm tools capable of producing approximately 20,000 12-inch wafer starts per month (WSPM). Once its bid gained approval, TI shipped these tools to its facility in Richardson, Texas, known as “RFAB,” targeting the manufacture of high-volume analog products. At approximately $550 million for 20,000 WSPM capacity, TI paid roughly 35 percent of greenfield costs (assuming greenfield costs of $80 million per 1,000 12-inch WSPM capacity). This is consistent with TI’s own statement that it expects RFAB to break even at 30 to 35 percent utilization.

A little over a year later, in mid-2010, TI acquired two fabs from bankrupt NOR-flash manufacturer Spansion in Aizu-Wakamatsu, Japan. One of these was a 300mm facility, from which TI shipped additional tools to RFAB.

Around the same time, in the summer of 2010, Maxim entered into a 300mm foundry alliance with Taiwan’s Powerchip Semiconductor Corporation. Maxim qualified a 180nm Bipolar-CMOS-DMOS process, used in power-management chips, in Powerchip’s 300mm fabrication facility and began shipping product in November 2010.

The advantages and limits of 300mm

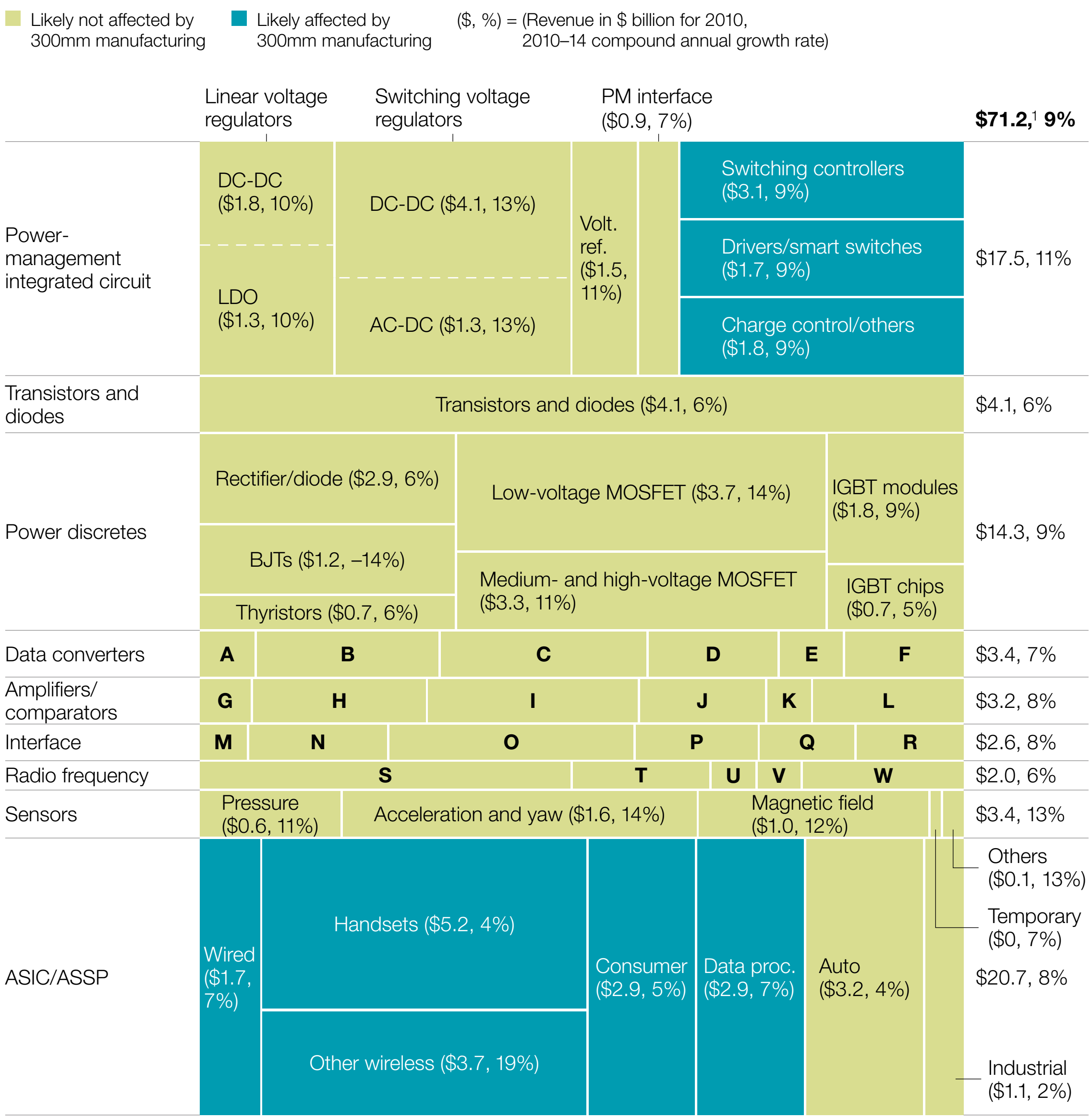
Advantages

Many are concerned that 300mm manufacturing in analog portends a costly and value-destroying cycle of large investments that the memory, microprocessor, and logic segments have already endured. Some players certainly have reason to watch these developments closely. As illustrated in Exhibit 1, the transition to 300mm manufacturing is most economical for high-volume products (such as analog application-specific standard products and power-management chips), which have sufficient revenue per stock-keeping unit to justify the nonrecurring engineering costs associated with requalifying the process on 300mm wafers.

The high volume requirement follows from the large number of die per wafer in 300mm manufacturing. For example, on a 250nm BiCMOS process (typically used for analog amplifiers)

Exhibit 1

The transition to 300mm manufacturing is most economical for high-volume products.



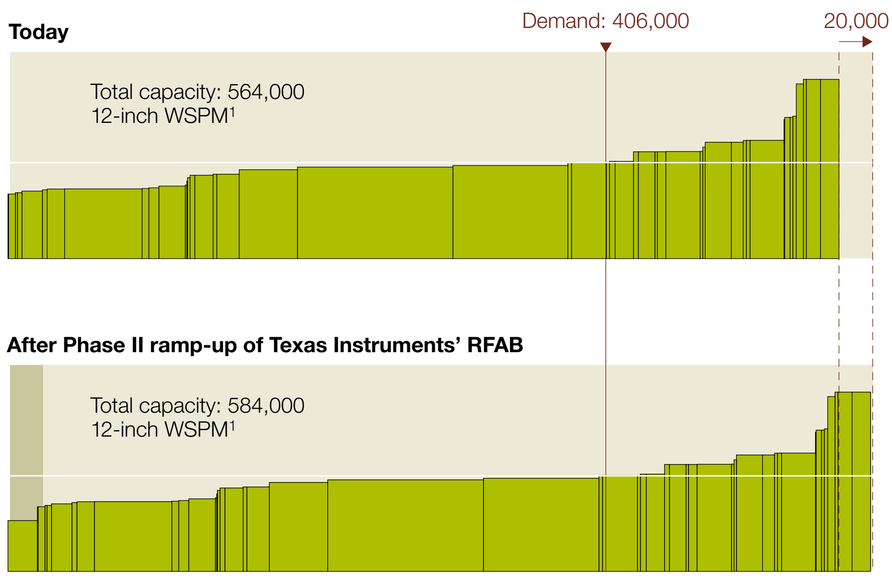
	Wired	Wireless	Consumer	Data proc.	Auto	Industrial
Data converters	**A** ($0.2, 3%)	**B** ($0.8, 15%)	**C** ($0.9, 3%)	**D** ($0.6, 4%)	**E** ($0.3, 5%)	**F** ($0.5, 7%)
Amplifiers/comparators	**G** ($0.2, 10%)	**H** ($0.7, 19%)	**I** ($0.9, 3%)	**J** ($0.5, 4%)	**K** ($0.2, 5%)	**L** ($0.7, 5%)
Interface	**M** ($0.2, 7%)	**N** ($0.5, 21%)	**O** ($0.8, 4%)	**P** ($0.4, 3%)	**Q** ($0.3, 3%)	**R** ($0.4, 7%)
Radio frequency		**S** ($1.0, 10%)	**T** ($0.4, 2%)	**U** ($0.1, –1%)	**V** ($0.1, 3%)	**W** ($0.4, 2%)

[1] Total may not sum due to rounding.

Source: iSuppli, 2010; McKinsey AMS database, 2008; *O-S-D report*, IC Insights, 2010; Gartner, 2010

Exhibit 2

The 2009 capacity cost curve for RFAB's relevant analog market shows that the increase in supply would not fundamentally alter pricing.



[1] Wafer starts per month.
Source: iSuppli Competitive Landscaping Tool 2010; SEMI World Fab Watch, May 2010; literature search; McKinsey analysis

used to manufacture a 4mm x 4mm die, a batch of 25 300mm wafers translates into 100,000 die, versus approximately 45,000 die for the same number of 200mm wafers. This factor increases further if 300mm manufacturing results in lower node width, which decreases die size.

The consumer and wireless segments are particularly attractive for 300mm manufacturing, since these segments traditionally have thinner margins due to higher competitive intensity and often use digital techniques to implement analog features, enabling these products to benefit substantially from the cost reductions that a transition to 300mm (and the node reduction that typically accompanies this transition) provides.

Limits

Industry segments or products outside these areas, however, are not likely to be significantly affected by 300mm manufacturing. Exhibit 1 shows that 300mm manufacturing could affect approximately one-third of the total analog and mixed-signal semiconductor revenue pool: in 2010 the potentially affected segments accounted for $22 billion of the $71 billion total. Furthermore, the existing 300mm players are not expected to fully exploit this potential anytime soon. Even after complete fitting out, TI's RFAB could drive approximately $3 billion in revenue—that is, less than 15 percent of the revenue for segments potentially affected by the shift to 300mm. Maxim is a significantly smaller player in this area.

A number of factors come into play that will define the limits of the transition to 300mm.

- First, at 20,000 WSPM capacity, RFAB will represent only 4 percent additional capacity in the high-volume analog market during the first phase of its ramp-up. The cost curve in Exhibit 2 suggests that a 4 percent increase in supply would not be enough in the near term to alter market pricing fundamentally across the potentially affected segments. Once RFAB is operating at full capacity, it will eventually be able to account for approximately 15 percent of overall capacity.

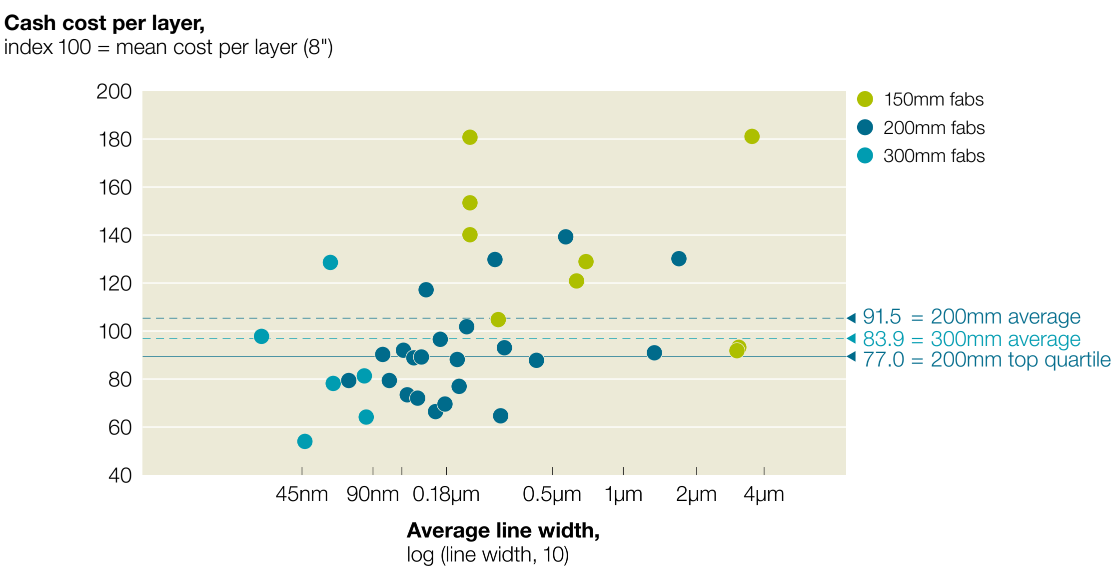
- Second, TI itself is not yet committed to a complete transition to 300mm manufacturing. Among the two fabs purchased from Spansion in mid-2010 is one 200mm facility that TI plans to continue running at 0.3 micron for high-performance products (such as data converters and power amplifiers).[4] In addition, in early 2010, TI agreed to acquire rival National Semiconductor in a $6.5 billion all-cash deal; 90 percent of National's product mix is high-performance 200mm analog chips.

- Third, while larger-diameter wafers are typically more cost effective, individual fab performance matters. Exhibit 3 presents our analysis of cash costs per layer, revealing that while the best-performing 200mm fabs outperform 150mm fabs, 150mm fabs outperform the worst-performing 200mm fabs. We expect that a similar dispersion will emerge between 300mm and 200mm fabs, with the best 200mm fabs outperforming the less efficient among 300mm fabs.

[4] http://www.eetimes.com/electronics-news/4204587/TI-buys-two-fabs-from-Spansion-Japan.

Exhibit 3

An analysis of cash costs for a range of fabs demonstrates that individual fab performance matters.



- Finally, improvements in wafer-manufacturing costs have a smaller impact on the gross margin of analog than of logic products. To begin with, as noted, analog products typically enjoy higher gross margins than memory and logic products. Analog products also have higher back-end costs as a proportion of total costs, as illustrated in Exhibit 4. Assuming an analog gross margin of 60 percent and an equal split between front-end and back-end costs, wafer costs will constitute approximately 20 percent of revenue for an analog product, versus 40 to 50 percent of revenue for typical logic products with gross margins of approximately 40 percent.

For affected players, a path to a successful response

For affected analog players, it will be cold comfort that some of their colleagues do not need to worry about 300mm manufacturing. For integrated device manufacturers that play in products or segments affected by its introduction, the time has come to examine strategic options. We believe that a path to a successful response will involve three steps.

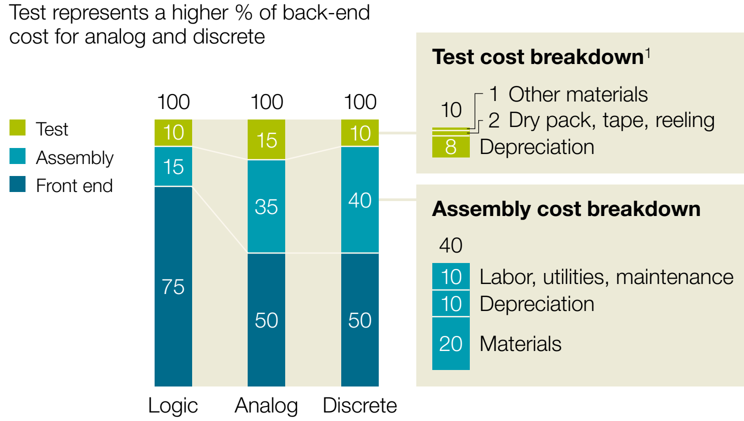
First, players must consider their high-volume analog portfolio and understand precisely what a transition to 300mm manufacturing will mean for them. Do they need to pursue a 300mm strategy? If so, can this best be done independently or in an alliance? A detailed cost-benefit analysis should assess potential benefits from larger wafer sizes, node shrinkage, and die-size reduction against the cost, schedule, and risk implications of a process transition.

Second, players must closely follow the market's evolution. In this area, a number of key questions

Exhibit 4

Analog products have higher back-end costs as a proportion of total costs.

Test represents a higher % of back-end cost for analog and discrete



"The ROI[2] on packaging improvements is higher than the ROI on front-end improvements for some product categories . . . improved thermal dissipation in the packaging allows the supplier to shrink the die size (and save on the front end) while still dissipating an equivalent amount of heat in a smaller area"

—Vice president of packaging at an integrated device manufacturer

[1]Total may not sum due to rounding.
[2]Return on investment.

Source: Expert interviews

should be considered, including what options are available to competitors, how soon competitors might react, and which manufacturing partnerships might be possible.

A continuum of options

Finally, players must craft a response strategy, which must be both comprehensive and consistent with the company's overall manufacturing and sourcing strategy. The options span a wide continuum. At one end is independent 300mm fabrication, along the lines of the TI model. Accordingly, companies would purchase used 300mm tools to install in their own fabs. While in 2011, the supply of used 300mm equipment is tight, the eventual transition to 450mm wafers in microprocessors or memory will likely flood the market with used 300mm equipment. A second option resembles the model pursued by Maxim, in which an alliance is established to source idle DRAM capacity. Further along the spectrum of responses is a transition to a fabless or fab-lite model, in which a foundry partner is encouraged to manage the transition to 300mm. Outsourcing high-volume analog products alone to a foundry partner—that is, ones that benefit from node reduction and 300mm wafer scale—might be the next point along the continuum of options. Last, affected players might work to improve productivity and operational performance in their current 200mm fabs, so they can compete more effectively against new 300mm analog capacity.

• • •

The effects of the transition to 300mm capacity on the analog universe will certainly be felt, but only in select segments rather than the industry as a whole. For players in the affected areas, it is not too early to begin tailoring their response to the 300mm challenge. The optimal approach to crafting a strategy is a carefully considered process that takes into account the specific features of a company's high-volume analog portfolio, the market's evolution, and the spectrum of viable responses, extending from "all-in" 300mm fabrication to none at all.

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Getting Mo(o)re out of semiconductor R&D

Excellence in the R&D function is only one piece of a world-class product-development strategy. Via a new diagnostic and jointly developed plan, we can significantly reduce time to market for new chips while also improving overall quality.

Harald Bauer, Felix Grawert, Nadine Kammerlander, Ulrich Naeher, and Florian Weig

Research and development is the lifeblood of the semiconductor industry—so it is no surprise that R&D tends to be the highest-pressure corner of this high-intensity business. Much of this pressure results from the fact that time to market is a crucial metric for semiconductor makers: speed, specifically on-time delivery, is a key success factor in a market characterized by tight design-in windows, shortening product life cycles, and relentless price deflation. For some, Moore's Law still sets the industry's pace; ever-rising investments and technology challenges, such as rising chip complexity, are also a factor. For others, the core challenge is mastering system design, which involves integrating hardware and software blocks, as well as various films, coatings, and layers, and ensuring they are customized to reflect customer and end-consumer preferences. Indeed, a number of leading-edge wireless semiconductor players now employ twice as many software engineers as traditional hardware engineers.

The impact on the industry is significant: for the top 20 semiconductor players, R&D costs have continuously risen and now account for more than 20 percent of revenues. The ratio of product life cycle to product-development time in semi-conductors is half that for a mobile phone and a third that for an automobile. And for the growing ranks of "fab lite" or fabless players, R&D excellence is the key differentiating factor.

Many institutions have a history of time and budget overruns, in addition to late adjustments to product specifications from the R&D department, resulting in angry customers. At the same time, changing customer expectations and requests for specifications lead to many new projects in the pipeline.

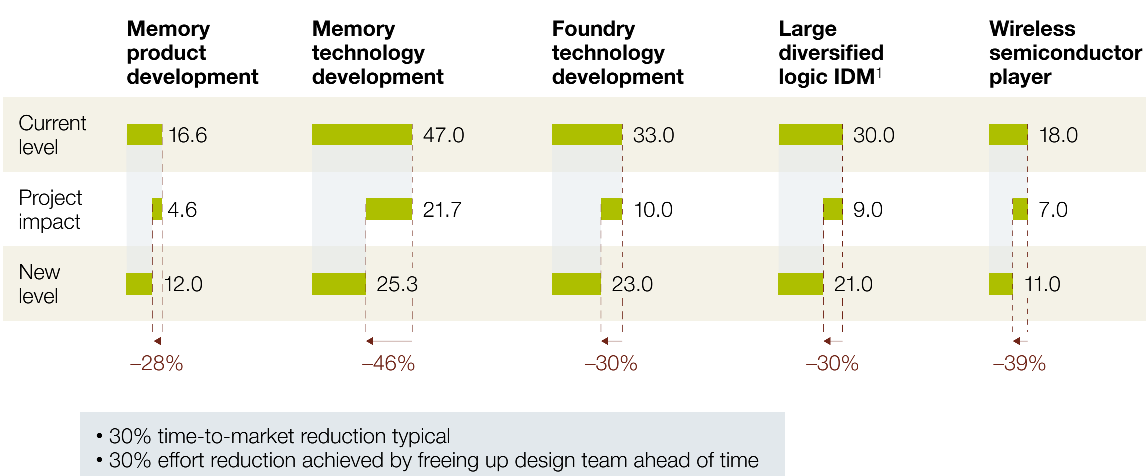
Unfortunately, the problem extends beyond a single department. Our experience suggests that at least a third of the solution relates not to R&D but to interfaces with other functions: marketing, sales, production, and even supply chain. Consequently, any response must begin with a broader diagnostic of the product-development process, in which all involved functions are engaged to develop a holistic picture of the situation. For example, a team typically analyzes one or two end-to-end learning cycles (say, a new feature, a debugging exercise, or a technology process-of-record variant) within a single project; the team examines the process—including the initial idea, implementation, testing and analysis, and the final decision—while observing all touchpoints, loops, interfaces, and delays throughout the organization.

Our approach, which incorporates levers to improve product development and has been implemented with five clients (including fabless players, memory integrated device manufacturers, and a logic foundry), can make a sustainable and decisive difference in performance. On average, these clients reduced time to market by 30 percent and maintained or improved quality (Exhibit 1). We first conduct a thorough

Exhibit 1

A proper transformation program can greatly reduce development time.

Product-development cycle time, months



[1]Integrated device manufacturer.

Exhibit 2

Specific challenges in integrated systems require tailored solutions.

Challenges	Approaches
• Insufficient breakdown of system features to requirements on individual hardware and software building blocks, leading to unclear development scope	**1** Structured requirements-breakdown process and tracking of breakdown via key performance indicators
• Serial development of hardware and software projects, extending development time	**2** Development model with parallel hardware and software development via virtual prototypes and step changes in development time
• Tests conducted only late in the development process and on the level of the entire system, leading to late identification of bugs	**3** Staged verification process starting with preverification on block level and a well-defined verification cascade, testing each module before integration into the system
• Separate projects and separate scope definition for hardware and software projects, despite need for close synchronization and interaction	**4** Joint definition of hardware and software projects and introduction of system milestones as “clock generator” that synchronizes hardware and software development
• Lack of accountability within the development of highly complex integrated systems that require the involvement of many experts	**5** Introduction of a hybrid organization with project deliverables handled by a virtual organization with functions responsible for delivery of work packages

diagnostic of the development process, and then we involve all affected departments in the design of a new methodology. Finally, we roll out the methodology, aiming to remove bottlenecks at various stages of the development cycle (Exhibit 2).

There is one important caveat: the approach deliberately focuses on product-development efficiency (number of products per input); it places less emphasis on effectiveness (impact of output products per input). It is, of course, better to develop a great product in an inefficient way than a poor product efficiently—but this is no excuse for poor efficiency. First, an efficient process simply provides the company with more outputs from the product-development process; increasing efficiency in time and effort by 33 percent allows the organization to develop 3 products instead of 2 using the same inputs. More important, by highlighting typical issues related to effectiveness, such as poor specifications or unrealistic timelines early in the process, making processes more efficient can help identify changes that will improve effectiveness, too.

Designing a transformation program for product development

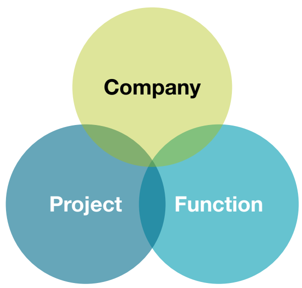
In general, the diagnostic looks at the end-to-end product-development process through three lenses: a company view, a line-function view, and a project view (Exhibit 3).

The company view focuses on basic higher-level facts about product development and the value at stake: R&D spend versus the competition; on-time, on-budget performance (versus the original plan) of projects considered both as an average and as a spread, or range; the basic organizational setup (that is, to determine whether the R&D footprint is fragmented inefficiently across several

Exhibit 3

A typical diagnostic considers three perspectives.

Relevant areas



Typical improvement levers

Company level	1	R&D portfolio management
	2	Organizational setup
Functional level	3	Predevelopment
	4	Reuse
	5	Definition of requirements
	6	Development flow: methodology
	7	Development flow: tool landscape
	8	System for key performance indicators and output maturity
Project level	9	Resource allocation and capability buildup
	10	Project management
	11	Engineering efficiency and removal of bottlenecks

sites); and the general balance of the portfolio with regard to risk and time to launch. The team also reviews current key performance indicators and incentives for product development.

The line-function view looks at the way competence is created and leveraged in a sample of different projects. This includes an analysis of the quality of predevelopment, the reuse of architecture and intellectual-property blocks, the definition of requirements, and the basic development methodology and tool flow.

The project view assesses the quality of the competences deployed within specific new product-development projects. The team considers aspects such as project-management skills, especially in light of project planning, resource allocation, and links to capability-building programs and individual engineer productivity.

Viewing the product-development process from each of these perspectives allows the team to focus on strategic and tactical dimensions, highlighting improvements from the organizational level to the individual-employee level. The diagnostic is conducted by a group of consultants and client employees who represent all core functions and data providers. Both quantitative and qualitative analyses (for instance, structured questionnaires or surveys) are used.

The diagnostic yields many insights. For example, it is not uncommon to see several (or even all) of the following bottlenecks in a single company:

- The footprint of the R&D organization is driven by legacy and individual sites that are not aligned with an overall R&D strategy; sites lacking clearly defined missions are a particular problem.

- Performance varies significantly from project to project. The root causes are usually unclear, as postmortems focus on technical issues, not on project management, where problems more frequently lie.

- Predevelopment priorities are not transparent, so solutions are not mature, which leads to intensive follow-up work on live projects.

- The development methodology does not optimally distribute engineering work among the different involved functions. This may be especially problematic for companies that have recently acquired software competence—they tend to treat software as an element simply added on to hardware; such organizations must design a truly embedded flow.

- Milestones, also known as stage or quality gates, are defined but regularly missed; meetings are poorly attended and not formalized; and meetings often end without decisions being made.

- Planned reuse of intellectual property is often limited to one instance, as requirements for the next generation of products change in subtle ways.

- The project manager's overall plan is out of sync with a plan from a subteam manager. Individual engineers have no insight into how they fit into the picture.

- Star engineers may work on more than five projects at a time, and they may consequently be preoccupied with firefighting.

The picture that emerges is often sobering—but it can also be encouraging. The size of the opportunity becomes visible, and a straightforward change story emerges: introducing sound methodologies and new ways of working can eliminate substantial waste from products and reduce stress for engineers, project leads, managers, and executives alike.

Based on a quantitative assessment of the total opportunity and the contributions of the different levers that can be pulled, the team prioritizes core levers for the transformation program. There are typically two or three themes related to enablers (for example, site strategy, resource planning and deployment, and IT flow), as well as three or four direct levers (such as quality output of predevelopment, development methodology, and project management). When

Viewing the product-development process from each of these perspectives allows the team to focus on strategic and tactical dimensions designing the transformation program, the team looks for a fair mix of line and project elements to ensure all stakeholders are involved in the change process.

It is also useful to touch different stages of the development process (for instance, predevelopment, the concept phase, the development phase, and ramp-up), which ensures that impact is widely visible. To quickly capture much of the opportunity, the team identifies debottlenecking adjustments among ongoing projects, rather than starting with one new project from scratch. These tactics help demonstrate broad impact early in the process, and they build enthusiasm to carry implementation forward.

Making change happen

Many programs to transform product development fail because the organization lacks a consistent method for the work, does not persist with the program as long as is necessary, engages in too much firefighting, and focuses too strongly on hidebound change processes. With regard to the last point, we generally insist that product-development transformations involve individual engineers directly or incorporate the views of colleagues whom the engineers respect. Although this is a basic rule of change management, it is essential in this kind of environment—after all, engineers tend to be skeptics until they see proof that a change will improve the situation.

As a consequence, teams overseeing the implementation of key levers must consist of both corporate management and important members of the technical hierarchy. Furthermore, they must act pragmatically at the outset of the program to convince colleagues of the program's worth by delivering quick wins. The first success factor will prove rather painful, because teams must dedicate critical resources to improving the future rather than addressing day-to-day problems. (Whether this is happening in and of itself constitutes an important gut check for the project's sponsor.) The second success factor is almost as fraught, as immature innovations are deployed live and move forward in actual projects, not in sterile pilots. Given these factors, quick wins are crucial for building and maintaining morale.

A few examples demonstrate how clients have driven change in their product-development organizations. One client identified the need for a large-scale upgrade of its development methodology (for example, it needed to deploy a semi-automated design methodology more broadly, promote higher reuse, and significantly improve virtual integration). The change was debated fiercely in the expert community. The client organized biweekly town-hall meetings, to which a series of experts and project leads were invited to make presentations on the various aspects of the new methodology based on real project experience. The speakers included both supporters and opponents of the change; each was asked to display the pros and cons of the new approach. In the course of the series, the data increasingly showed the superiority of the new approach, and the engineering community embraced the need for change.

Another client needed to counter the lack of connection among the priorities of large projects involving more than 200 engineers with the tasks of individual contributors to these projects. The company introduced a standardized set of planning and alignment meetings to cascade through the project hierarchy, culminating in daily five-minute team huddles at the working-team level, to track progress against the weekly plan. Many, especially senior engineers, protested the measure, because they felt it was a sign of mistrust and of a command-and-control attitude. However, the team leads were also trained to use the short huddles to identify roadblocks faced by team members that could be isolated and removed. Soon, many engineers had personally experienced measurable efficiency gains; this made the new way of working popular. For another company, a similar approach ultimately led to the development of a card for engineers to carry in their wallets that outlined the rights of an engineer on one side and the duties of an engineer on the other. Engineers were quick to point to their rights (which included having clear priorities, visibility into the project plan, and an efficient work environment), while team managers reminded them of their duties with regard to making work transparent, remaining committed to the plan, and speaking up about bottlenecks.

A fourth client had to deal with the ineffectiveness of its predevelopment department. The project team decided to organize a "predevelopment summit," which brought together the company's top 50 technical experts and R&D managers for a full day. In a series of preparatory meetings, the individual module and unit process owners pitched their proposals to a group of peers, project leads, and representatives from technical marketing and management. This helped them sharpen their proposals, anticipate questions, and conduct initial prioritizations. The summit itself matched all proposals to the overall R&D strategy, forcing the technical experts to rank them (using an anonymous vote) before passing the final decision on to the management team. The predevelopment process was further improved by having the leader of the unit and the core program leads present together to the management team on progress each week.

• • •

These examples offer a glimpse of the innovation, rigor, and outreach involved in the improvement projects that make up a larger program. Although companies can generate initial success stories in as little as 2 to 3 months, it may take 6 to 10 months to realize the full impact from pilots. Given the time it takes for technology and product development at larger semiconductor companies, it may be two to three years before the entire organization sees the total potential. By that time, however, the company will have profited significantly from the transformation, which will have freed up critical resources for more and higher-quality product development. ○

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LED at the crossroads:
Scenic route or expressway?

Although adoption of LED lighting has been slow, roadblocks can be overcome with a comprehensive approach that includes operational improvements, better marketing of products, and other efforts.

Oliver Vogler, Dominik Wee, and Florian Wunderlich

The advantages of new LED lighting technology are well tested and beyond doubt. Nevertheless, LED lamps have achieved little market penetration and are predicted to make far slower progress than comparable disruptive technologies. Research conducted by McKinsey's LED Competence Center has revealed the underlying reasons for the slow uptake; if manufacturers, retailers, and regulators collaborate to overcome the five major barriers to adoption we have identified, LEDs could dominate the lighting marketplace by 2015.

LED: Environmentally and economically superior

LED is a revolutionary lighting technology. It offers a number of important features, including many that cannot be matched by existing incandescent, compact fluorescent (CFL), or halogen lights. Among LED's advantages are greater color variability, "instant on" capability, dimming capacity, and freedom in design. The efficiency of LED bulbs makes them significantly superior to CFL today with regard to total cost of ownership. LED bulbs can generate more than 100 lumens per watt of electricity, compared with 60 to 75 for CFLs; they also last three to five times longer. LED's fully loaded costs become lower than those of typical fluorescent lights in roughly six years.

LEDs are also superior from an environmental perspective. They contain no mercury, so their

disposal is significantly less problematic than that of CFL or traditional fluorescent tubes. From a carbon-abatement perspective, LED's energy efficiency offers the potential for substantial savings. Compared with traditional incandescents, LED lamps can reduce energy consumption by more than 80 percent.

LED penetration: The roadblocks and how to overcome them

In spite of LED's advantages, even optimistic market forecasts predict that LED retrofit lightbulbs will not achieve 50 percent household penetration in the United States for 10 years or more. This pace would be slower by half or more than was achieved by DVDs, broadband Internet, and television.

To understand what is holding LEDs back, McKinsey conducted research involving store visits and a survey of key LED industry players. The results highlighted five key roadblocks, for which we developed solutions based on both existing McKinsey knowledge and new insights derived from proprietary research, including a conjoint analysis of consumer shopping behavior.

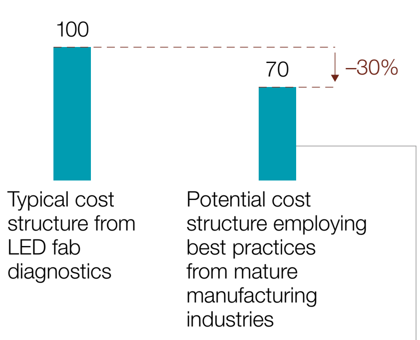
1. LED unit costs are too high
   Not surprisingly, our survey shows that industry leaders agree that unit costs are the

Exhibit 1

LED adoption can be accelerated by applying best practices in manufacturing.

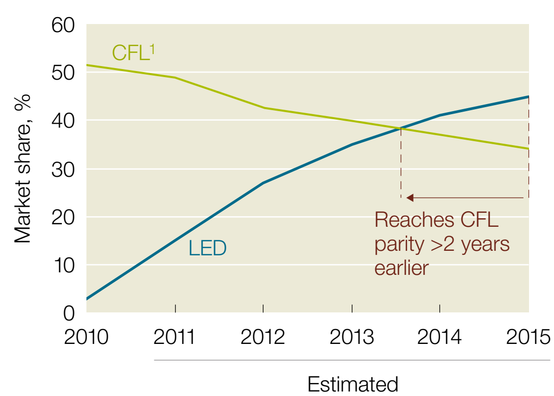
Learning from industry best practices . . .

Average LED cost-improvement potential based on McKinsey LED benchmarking



Measures
- Use larger-scale wafers
- Increase automation levels
- Use large-scale fabs
- Employ advanced lean-manufacturing methods such as complexity management

. . . would accelerate LED market adoption



[1]Compact fluorescent lights.

Source: McKinsey LED benchmarking initiative; KLA-Tencor; McKinsey conjoint model on the lightbulb market biggest roadblock for LED right now. At €20 to €40, LED is still four times the price of an equivalent CFL in the 40-watt-equivalent product range.

Solution: Reduce costs by applying manufacturing best practices

By employing best practices drawn from mature manufacturing industries (for instance, increasing yield and automation levels), we believe that lowering the cost of LED lamps by as much as 30 percent as a one-time effect could be readily achieved in the short term. The one-time reduction would augment a typical annual cost reduction of around 20 percent, according to most experts (Exhibit 1).

Our analysis indicates that if manufacturers pass on the cost reduction to consumers, LEDs could achieve the same market share as CFLs (about 40 percent) by 2013, two years ahead of current forecasts.

2. Product positioning at retail is weak

Our store visits showed that LED lamp manufacturers are not making sufficient investment in retail presentation. We encountered signage that muddied the distinction between the energy efficiency of LED and CFL bulbs, and 70 percent of the stores we visited had no dedicated section for LED bulbs. More than half the stores in our tour had very limited assortments of LED bulbs, with only typical white bulbs on offer in only the most standard wattages.

Solution: Offer clear and informative consumer guidance

Our analysis reveals that a handful of improvements in merchandising techniques could significantly increase consumer adoption (Exhibit 2).

Applying their trade-spend budgets as necessary, manufacturers should encourage

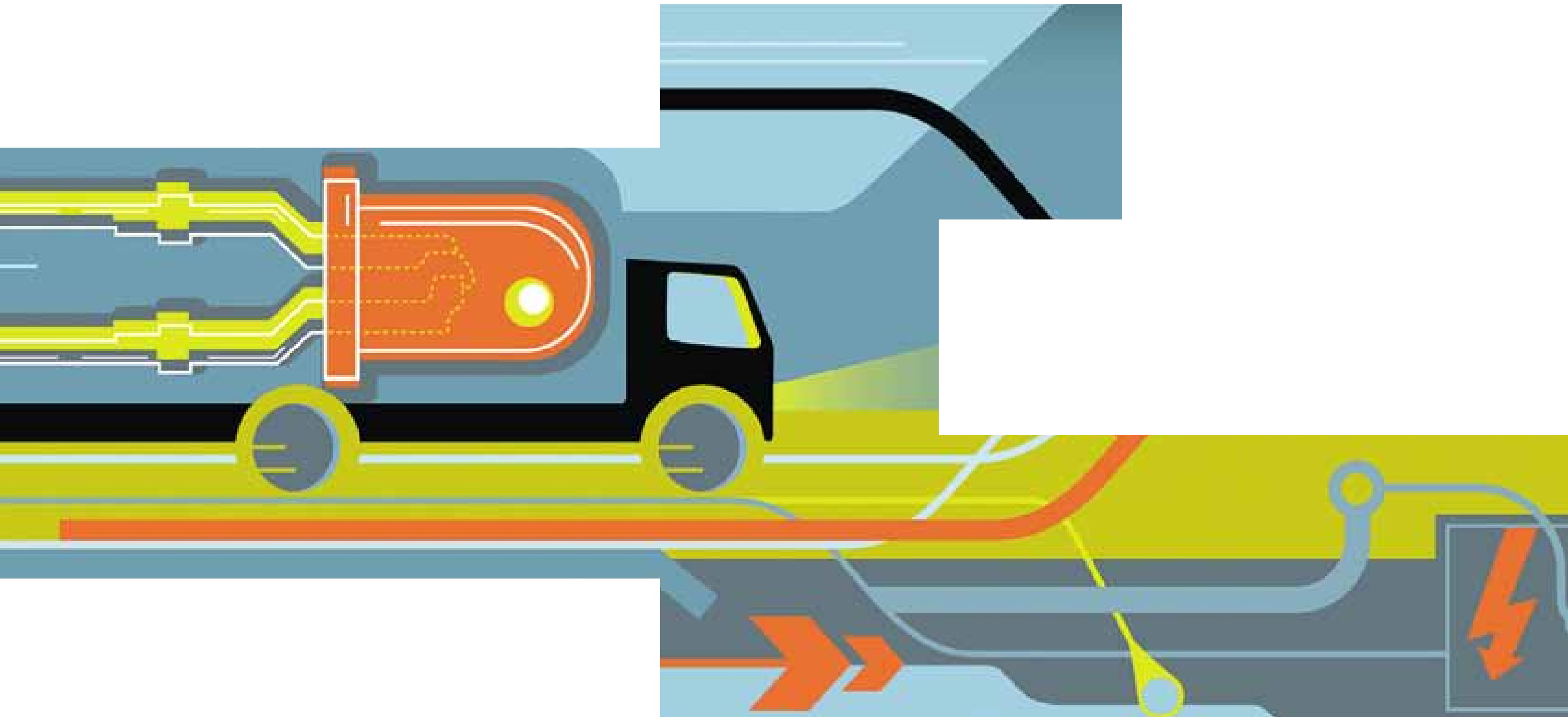
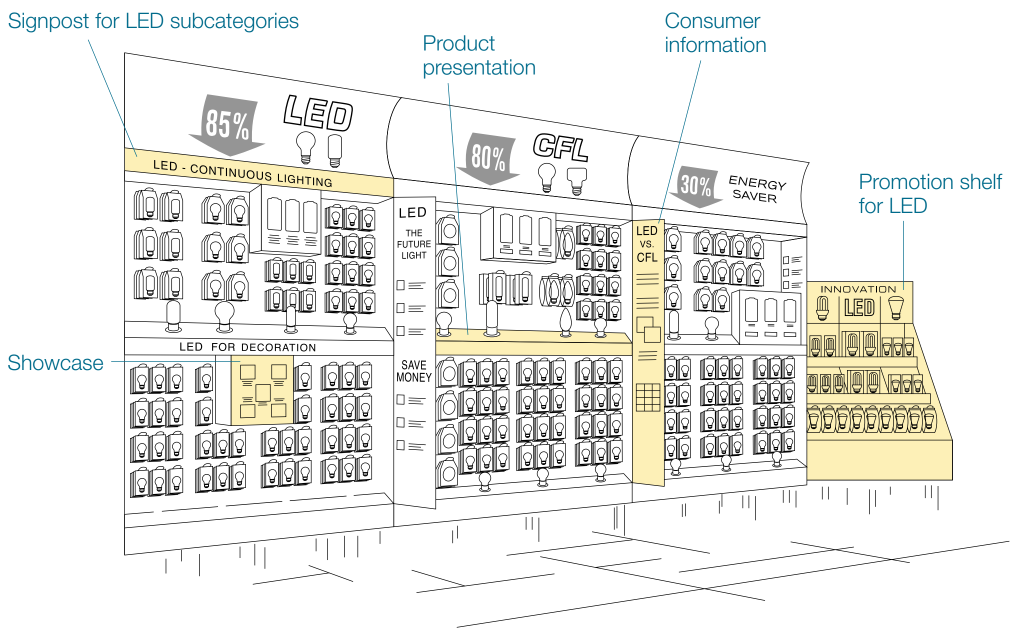


Exhibit 2

Clear and informative guidance for consumers is essential when marketing LED products.



Source: Store visits (n = 12, July 2010, Munich)
Illustration by Lloyd Miller

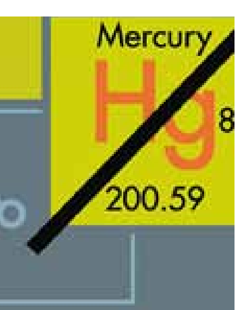
retailers to do a number of things: segment lighting technologies for display, feature LED products on special promotional shelves and on the ends of aisles, and deploy showcases enabling comparisons of brightness, color, and temperature from technology to technology. Manufacturers should also be sure that consumer-information literature is displayed beside the segmented LED products.

3. Principal-agent conflicts abound

In most commercial lighting situations (for example, corporate offices or building lobbies), builders make the majority of lighting decisions based on initial cost rather than longer-term benefits. On the other side of the ledger, the tenants pay the operating cost, meaning that they would likely prefer LED, if they were in a position to make the decision.

Solution: Create third-party lighting service providers

These interests, now in conflict, create an opportunity for the introduction of a new business model to satisfy both sides: lighting service provision by a manufacturer, a utility, a facility-management company, or a third party. A business of this type would sign contracts to provide not only the up-front investments, perhaps with financial participation from an investor, to enable LED lamp installation, but would also provide



Switching from incandescents to LED can actually yield a profit from CO_2 abatement of approximately €140 per ton of CO_2 abated, due to the energy-saving potential of LED

the maintenance and upkeep of the LED fixtures and charge occupants an hourly rate for light. By removing the purchasing decision from the builders, such a provider could price its services to begin delivering on the total-cost-of-ownership promise of LED to customers from the very first day, while also earning a decent margin for its services.

We calculated, for example, that by supplying and maintaining street lights for a city of one million people, an LED provider could generate energy savings on the order of 22 percent. At average rates, this model would save the municipality roughly €2.3 million per year, mainly through electricity savings.

Corporate customers could also benefit from such an arrangement. Their lighting costs would be reduced due to lower energy consumption, and the corporations themselves would bear none of the up-front investment costs. In addition, the maintenance burden associated with lighting would be reduced and completely outsourced.

4. Direct regulatory support is lacking

Despite bans of incandescents in more and more countries, LED adoption has little direct government support in the consumer sphere against competing traditional lighting alternatives like CFLs. In contrast, other energy-saving technologies enjoy more support: Germany, for example, provides €2.4 billion in solar-panel subsidies per year (paid by consumers), while the European Union is considering strong regulations to reduce CO_2 output from automobiles and other medium-size vehicles from 3.5 to 16 tons. Analysis shows that solar subsidies achieve CO_2 abatement at a cost of €80 per ton, and emission reduction in cars achieves this at a cost of roughly €190 per ton.

Solution: Publicize the remarkable environmental and cost advantages of LED

Our analysis reveals that switching from incandescents to LED can actually yield a profit from CO_2 abatement of approximately €140 per ton of CO_2 abated, due to the energy-saving potential of LED (Exhibit 3).

LED manufacturers have an irresistible case for their technology, which must be presented to regulators. A basic calculation shows that by funding LED retrofits at the same level as solar subsidies (€2.4 billion), Germany could abate 50 megatons of CO_2 as a result of the lower prices and higher penetration this would achieve. This is a tenfold savings over what the solar subsidies are projected to deliver.
In the European Union, if governments

Exhibit 3

LED lighting is an economically attractive means of achieving CO_2 abatement.

	CO_2 abatement in vehicles and solar comes at a cost . . .		**. . . but LED offers CO_2 savings and has positive TCO[1]**
CO_2 reduction lever	Reduce emissions in CO_2 per kilometer for vehicles	Introduce solar-power systems	Switch incandescent to LED
Cost per ton of CO_2 abatement, € per ton CO_2	–190[2]	–80	140[3]

[1]Total cost of ownership.
[2]Reduction of CO_2 in 2015 due to efficiency improvement in medium-duty vehicles of 3.5 to 16 tons.
[3]Assumptions for 2015: price – LED ~€20, incandescent ~€0.6; luminous efficacy – LED 150 lumens per watt, incandescent 12 lumens per watt.

Source: European Commission; McKinsey CO_2 abatement cost curve

mandated adoption of LED lighting for traffic signals and street lights, the programs could contribute significantly to the “20-20-20” EU goal (a 20 percent CO_2 reduction to be met by 2020).

5. Technology transitions create significant uncertainty

Examples of earlier technological transitions reveal risks as well as benefits for incumbent players. When cameras shifted from analog to digital in less than 10 years, for example, companies like Leica nearly vanished from the market in Germany, while others like Canon managed to increase market share.

Solution: Follow the lead of successful traditional semiconductor players

When managing the transition from traditional lighting to opto-semiconductors, incumbents can incorporate the factors that made traditional semiconductor players successful. For example, incumbents can rigorously manage an R&D road map to realize 20 to 30 percent annual cost reductions, or they can build a learning engineering organization to bring yield curves up quickly (starting at less than 10 percent). They can also employ fast decision processes to manage product life cycles of less than one year and institute sophisticated planning processes to manage volatility of more than 30 percent in volumes year to year in combination with significant capital commitments.

The road ahead: Shifting into high gear

The five roadblocks that we have discussed have kept LED lamps in the slow lane to adoption, with society and consumers largely missing out on their great potential. We have indicated our strong belief that the industry can overcome them, by acting in close partnership with component manufacturers, retailers, and regulators. A cleared path to accelerated LED adoption will also lead to a sustainably profitable, large-scale LED business.

In our base case, LED retrofit could achieve 37 percent penetration by 2015, a scenario largely in line with the industry's expert consensus of 30 to 35 percent. This rate can be accelerated by the comprehensive approach we have indicated to the five main barriers: making operational improvements to drive down costs, improving the marketing of LED products in stores, establishing third-party lighting providers for the commercial markets, successfully attracting government support via subsidies, and increasing focus among manufacturers on LED's potential.

By overcoming these five barriers, the industry could drive a five-year LED retrofit adoption rate above 50 percent. At that point, LED would become the dominant technology in consumer and commercial lighting, providing the industry with a crucial new source of profits for years to come. ○

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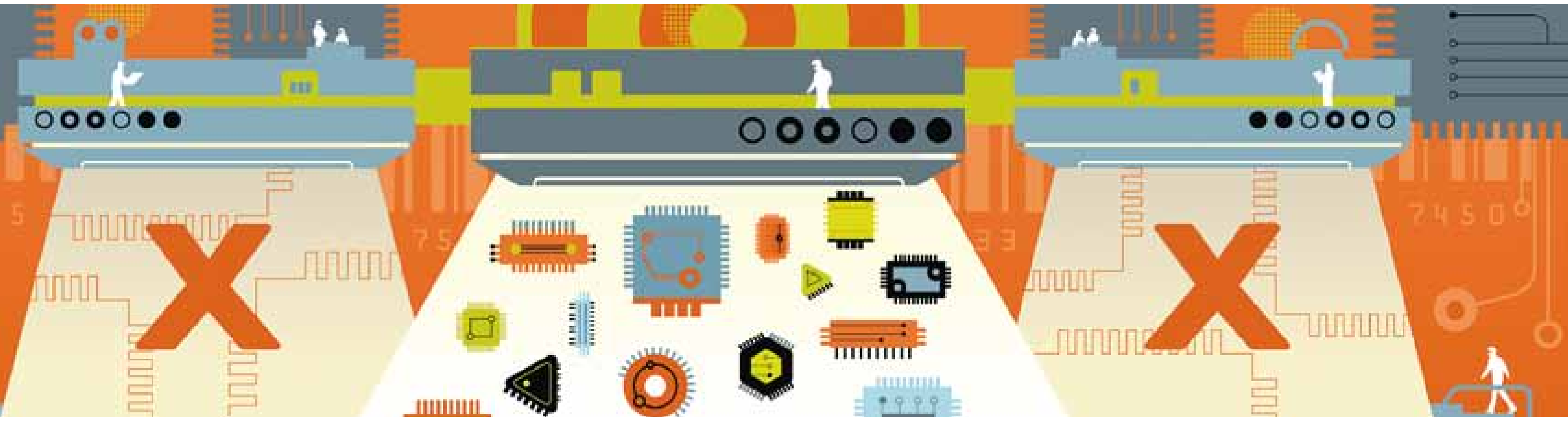

Mastering variability in complex environments

Variability adds cost to semiconductor production systems, but the ability to cope with it can also be a critical source of profit. A new approach goes beyond traditional tools to help companies control variability in their processes and make intelligent trade-offs in order to maximize return.

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Iana Kouris,
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Thomas Sigrist,
Jan Veira,
and Dominik Wee**

Semiconductors are among the most complex products manufactured today. That fact, in combination with the pace of change in the industry and the inherent difficulties in managing dynamic production environments, leads to up-and-down performance. After all, the need to produce a portfolio of different products, each of which requires a different amount of time or resources for production, inevitably creates inefficiencies, which result in financial losses. These losses can arise either from a drop in the utilization level of expensive labor and equipment or by an increase in lead times[1] as material waits in queues. Traditional methods for the optimization of production and other systems—most famously, lean—seek to eliminate variability completely, aiming to level demand and balance flow within a system. However, in many production situations, some variability is inevitable, so manufacturers must seek additional tools.

Managing variability in a sophisticated fashion can have positive effects for semiconductor manufacturers, creating an opportunity for them to distinguish themselves from their competitors.

The particular traits that cause variability in the semiconductor industry include dramatic advancements in technology, rapidly evolving customer demands, and a growing demand for specialty products. The variability that each of these forces introduces has a strong impact on

[1] Time between production start and production end of a wafer, including processing and waiting time.

profitability. Market demand and intense product-development activities require an expanding menu of different chips in ever-smaller quantities. Yet the popularity of a given product cannot always be predicted reliably, and therefore it is possible to be blindsided by sudden spikes (or sudden drops) in demand.

Even at the best of times, then, variability presents a challenge. However, the recent global recession revealed the ways variability can make a tough situation worse. During the recession, excess capacity was so high that 5 of the top 10 semiconductor companies reported material losses as a result. Even Intel, the standout financial performer in the sector, reported a loss of $1.1 billion in its 2010 annual report—a loss attributed specifically to excess capacity. If more sophisticated management of variability could mitigate any degree of excess capacity, it could make a substantial difference during the next down cycle.

A new approach has been developed to help semiconductor companies manage this uncertainty. This approach allows companies to openly ask a question that pertains to many if not all production systems: what is the quantitative relationship among variability, lead time, and utilization? By quantifying the impact of changes in lead time and utilization on variability using a new operating-curve methodology, semiconductor players can manage that variability—specifically, the variability that is left after more traditional tools such as lean have been taken as far as they can go. The ideal proceeding, now practiced by some leading semiconductor companies, is to identify the "sweet spot" in the management of their production systems—a spot determined by as much reduction of variability as possible, along with effective management of the remaining variability.

Use well-known tools

As noted, fast technological progress and rapidly changing customer demand make it hard for semiconductor manufacturers to control variability. However, significant opportunity exists to reduce variability in the production system.

The first step is to apply classical tools, such as lean manufacturing. Lean seeks to maximize the throughput of a production line by identifying and eliminating waste from the steps that cause bottlenecks in the process, with typical improvements of 20 to 30 percent. In semiconductor manufacturing, three sources of waste are prevalent: loss of availability (scheduled and unscheduled downtime), loss of utilization (change-over time, idle time, and loss of speed), and loss of quality (rework and scrap). By quantifying these three sources of waste, lean can identify "hidden" capacity in both leading-edge and lagging fabs, with different kinds of improvement levers applied. A focus on automation and handling inside the tools is most valuable for leading-edge fabs. Lagging fabs typically benefit most from the application of operator-efficiency levers.

In pursuit of a competitive advantage, some leading semiconductor firms are now moving beyond these traditional tools to apply new levers to optimize high-variability production environments. For example, a sophisticated approach to maintenance management can reduce the variability caused by equipment failures while minimizing the impact on production speed of planned maintenance events. One semiconductor fab reduced lead time per wafer by 20 percent by splitting a small number of relatively long maintenance shutdowns into a larger number of short ones (Exhibit 1). Even though the new strategy meant production lines were shut down for 15 percent longer

Exhibit 1

Splitting maintenance events can increase speed, despite reducing overall equipment availability.

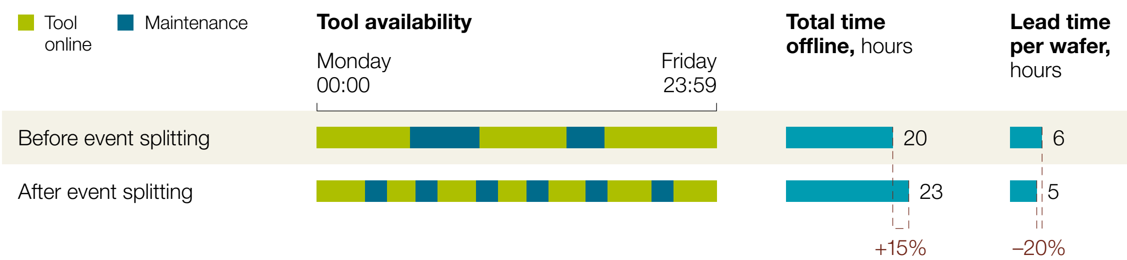
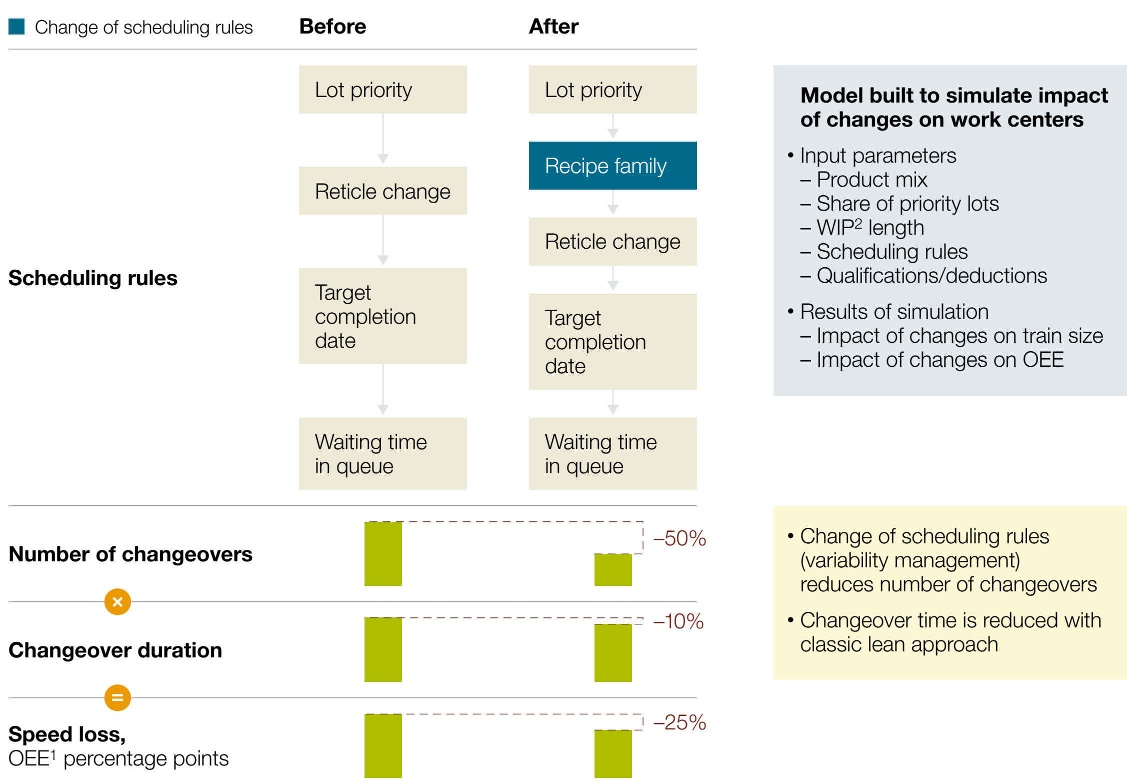


Exhibit 2

Clever batch sequencing reduced the number of changeovers—and lean methods made them faster.



[1]Overall equipment effectiveness.
[2]Work in process.

in total, the shorter stops kept material flowing more quickly through the system.

Optimizing manufacturing lines within a production facility helps, too. Companies can often dedicate particular lines to certain types of products, minimizing variability in individual lines and allowing each line to be optimized to suit specific product requirements. Some lines may be optimized for high-volume production, while others concentrate on specialty products.

Advanced batching and scheduling systems also help to reduce variability in production. By grouping different products with similar "recipes," for example, companies can minimize the number and effect of changeovers. Exhibit 2 shows how a semiconductor line used a combination of better sequencing and traditional lean tools to reduce both the number and the length of changeovers between batches, leading to a 25 percent reduction in speed losses.

Another important challenge in many environments is batch prioritization. Some jobs must be completed more quickly than others, either because customer requirements call for extra speed through the process or because waiting at one point will result in low utilization further downstream. Unfortunately, adjusting equipment to handle priority batches often incurs extra losses and delays. By establishing optimal rules for batch priorities, companies can ensure that priority batches are handled efficiently, without an excessive cost or time penalty.

Manage the rest of the variability

While not quite universal, attempts to minimize variability in production systems are widespread in most manufacturing companies. The methods described above can be successful in reducing variability to a large extent—but they cannot eliminate it completely. It is also the case that some variability-reduction mechanisms will prove not to be worth the cost. As a consequence, all semiconductor companies will reach a point at which variability has been reduced as far as is possible, or as far as is economically viable. What then?

The next challenge for a fab is to decide how it should operate its systems with the variability that remains. At this point, we recommend the introduction of an operating curve to calculate the effect of variability on a system. This curve is based on a theoretical approach known as queuing theory. Developed in academia in the 1970s, queuing theory has proved applicable in industrial applications over the last 10 to 15 years. Every production process has its own operating curve, which can be plotted using data on output, variability, and speed. The curve shows how different combinations of utilization (along the x axis) and lead time (along the y axis) generate different levels of variability (Exhibit 3).

A "perfect" production system with no variability at all, a hypothetical car plant perhaps, has an operating curve like the dotted line in the exhibit. Products flow smoothly through the process, and increasing volumes have no effect on lead time, so the equipment can achieve its maximum possible utilization.

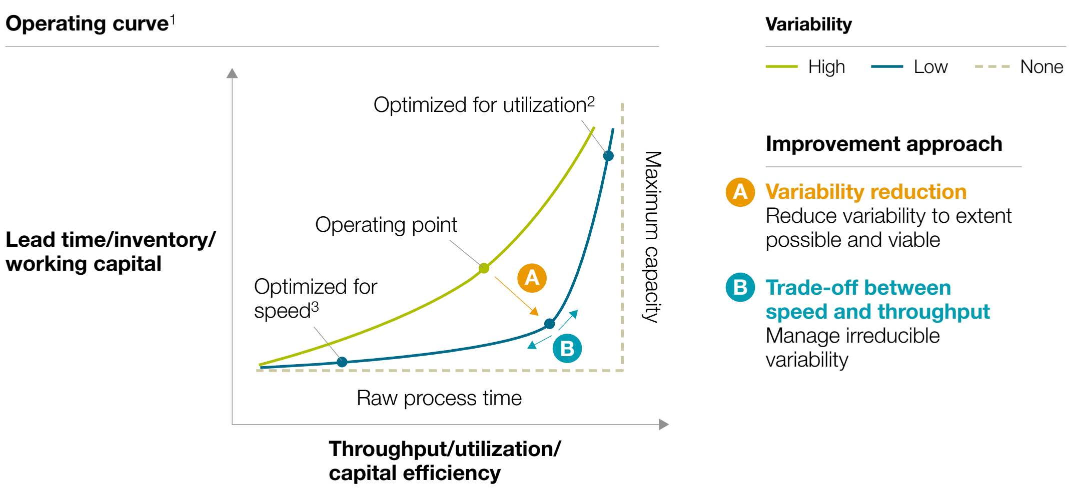
When variability is introduced, the operating curve looks more like the solid lines in the exhibit. The more the production assets are utilized, the longer the overall lead time becomes, as work in process increases in order to get the best out of the equipment on the line. To optimize systems with variability in them, their owners can use two levers: they can try to reduce variability wherever possible, as discussed above, moving the curve lower (that is, to the right). Then they can examine the curve for the optimal operating point, the place where utilization is maximized, without producing unacceptably long lead times. This is the most profitable point of operation.

In essence, the operating curve quantifies the trade-off between speed and utilization that every system must face in the presence of variability. Our experience suggests that building a reliable curve requires several months' worth of production data. This amount of data is at once statistically significant and sufficient for clients to see the financial impact of decisions that affect speed and utilization. It also allows clients to compare the impact of reducing variability using various levers with the cost of doing so.

Most semiconductor plants produce a combination of high-volume "commodity" products and lower-volume runs for specialty products. These plants are hugely expensive to build and run, with the result that utilization has traditionally been a priority for plant operators at the expense of speed. When one semiconductor manufacturer decided to take a new look at its operations, it realized that reducing variability and finding a new point along the operating curve would have a positive impact on its profits. First, the company took all the economically viable steps it could to reduce variability losses in its production system. Next, it made the trade-off described above and decided to reduce

Exhibit 3

Different combinations of lead time and utilization generate different levels of variability.



[1]Bending of the curve is determined by the system's variability.
[2]High work in process (WIP); high utilization; low speed.
[3]Low WIP; low utilization; high speed.

overall utilization in order to improve speed. The result, after an 18-month improvement effort, was a 20 percent decrease in manufacturing costs.

• • •

The best semiconductor companies are applying these two fundamental levers in an iterative way, working with their customers to control the demand for variability, relentlessly improving their production systems to reduce its impact, and adjusting their operating blend to make the best of the remaining variability. Soon, we expect to see variability management added to the arsenal of standard manufacturing methodologies in all companies: lean focuses on reducing variability, and the approach presented here will reduce the costs associated with the variability that lean cannot eliminate. ○

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