Managing Complexity & Change in the Semiconductor Ecosystem

Findings from the Wharton-ATREG Industry Study

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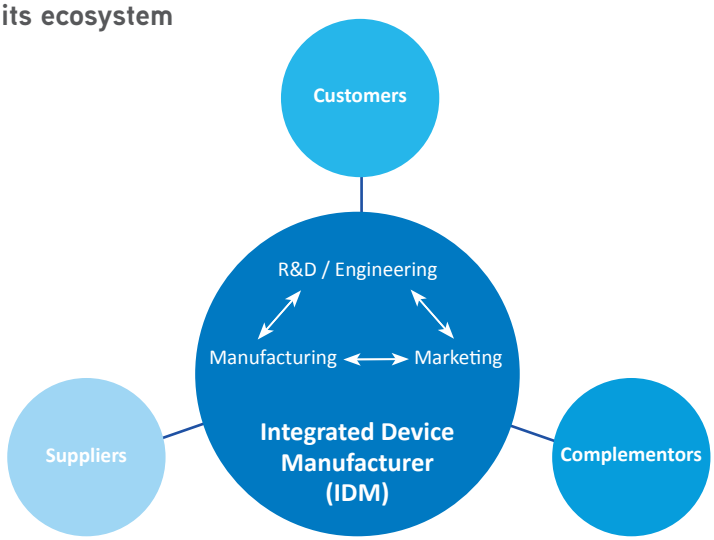
Executive Summary

The quickening pace of change combined with increasing technological and market complexity makes the semiconductor industry one of the most challenging environments in which to compete. As a result, many companies are redesigning their business models not only within the company itself, but also at the collaborative interface between the company and its diverse set of partners. An explicit assumption underlying this strategy is that the ability of a semiconductor company to create value from its own products and technologies is critically dependent on its business ecosystem comprised of suppliers, customers, and complementors. However, the success of such collaborative innovation models is often constrained by the technological and organizational challenges that companies face in collaborating and coordinating their activities within their respective ecosystem.

Figure 1: IDM firm and its ecosystem



We designed the Wharton-ATREG Semiconductor Ecosystem Study, part of a two-year research effort, to provide a systematic analysis of the nature of challenges and opportunities faced by integrated device manufacturing (IDM) companies that have traditionally depended on their internal manufacturing resources. There are several specific objectives that we hoped this survey would be able to address for the global semiconductor community. First, the findings provide a first-of-its-kind, inside-the-box view of how today's IDMs organize and manage their manufacturing activities and the nature of their interactions with foundry suppliers. Second, a company's success in developing and commercializing new innovations is shaped not only through superior manufacturing activities, but also through collaboration with its customers and complementors. Finally, the study's reported results provide some key indicators of semiconductor companies' technology strategies and outcomes, such as the different sources of intellectual property (IP), the extent of IP reuse, the nature of competitive differentiation, and time-to-market drivers. We believe that the findings from this study will help semiconductor industry executives benchmark their business models and design their organizations, so they can leverage their internal capabilities as well as those within their ecosystem.

Key Findings

The results of this study are based on detailed responses received from more than 50 senior executives at 23 publicly listed IDM companies, including 11 of the 20 largest IDMs based on 2011 annual revenue (see more details in the *Research Methodology and Demographics* section on page 23). In order to contrast the different types of manufacturing business models in the semiconductor industry, we compared some of the reported results on the manufacturing activities from IDM companies with those from fabless companies.

Fabless company data came from an earlier study administered by Professor Rahul Kapoor in collaboration with the Global Semiconductor Alliance (GSA) whose findings were published in the report titled *Collaborative Innovation in the Global Semiconductor Industry:* A Report on the *Findings from the 2010 Wharton-GSA Semiconductor Ecosystem Survey.* The findings of that report which is available at www.gsaglobal.org/publications/whartongsastudy/ are based on detailed responses received from senior executives at 37 publicly listed and 25 private fabless semiconductor companies.

IDMS' MANUFACTURING ORGANIZATION AND THIRD-PARTY MANUFACTURING

- **Internal structure:** 61% of IDMs represented in the sample use a centralized structure where manufacturing activities are organized at the corporate level rather than within separate business units.
- **Foundry outsourcing:** 74% of surveyed IDMs reported outsourcing at least 10% of their total silicon manufacturing to foundry suppliers.
- **Foundry service offering:** 43% of survey participants reported offering their internal manufacturing capacity to other semiconductor companies.

INTELLECTUAL PROPERTY AND PRODUCT DEVELOPMENT

- **IP reuse:** On average, an IDM reuses about 73% of design IP in the revision of an existing product design and about 44% in a new product design.
- **Source of IP:** A large proportion of IP for IDMs continues to be internal (84%) with some IP dependence on third-party IP firms and foundry suppliers.
- **Time-to-market:** The average time-to-market, defined as the period from design start to mass production, is about 11 months for a revision of an existing product design. It increases to about 17 months for a new product design.

IDMS' RELATIONSHIPS WITH FOUNDRY SUPPLIERS

- We evaluated the extent of collaboration between IDMs and their foundry suppliers in three different ways: **(1)** the extent to which a supplier shares different types of information with the IDM, **(2)** the extent to which a supplier is involved in the IDM's value-creating activities, and **(3)** the extent to which both the IDM and the supplier customize their activities towards each other.

- As compared to internal manufacturing, foundry suppliers share less information and are not very involved in IDMs' value-creating activities. The degree of customization between IDMs and their foundry suppliers is also significantly lower than what is achieved between internal manufacturing and business units.

- As compared to internal manufacturing units, foundry suppliers tend to be especially tight-lipped with respect to cost and proprietary technical information, and exhibit little involvement in IDMs' cost reduction and product design activities. IDMs tend to exhibit the least amount of customization with respect to designing their products using foundry suppliers' proprietary design libraries.

- IDM companies generally perceive their foundry suppliers' performance to be good or very good with respect to suppliers' technical competence, process quality, responsiveness to problems and inquiries, and capacity allocation. However, they seem less satisfied by the suppliers' price competitiveness.

DIFFERENCES BETWEEN FABLESS AND IDM COMPANIES[1]

- In general, as interpreted from responses on suppliers' information sharing and involvement in companies' value-creating activities, the relationship between IDMs and their foundry suppliers is much more at an arm's length than between fabless companies and their foundry suppliers.

- IDMs do not seem to customize their products as much to a specific foundry's process as do fabless companies. However, foundry suppliers seem to be customizing their processes and operations much more for IDM companies than for fabless companies.

- Overall, IDMs are slightly more satisfied with foundries than are fabless firms. The differences are more pronounced for perception regarding foundries' price competitiveness, manufacturing cycle time, and capacity allocation.

- IDMs are generally faster to market with new product designs on existing manufacturing processes whereas fabless firms are faster to market with new designs on new manufacturing processes.

IDMS' CUSTOMER RELATIONSHIPS

- Original equipment manufacturing (OEM) customers of IDM companies extensively share information on market trends as well as product development status and plans, but information sharing is much lower for customers' product costs and volume projections.

- On average, IDMs seem to be most involved in their customers' cost reduction and long-term technology roadmapping activities and less involved in underlying product development.

- In general, there is a significant asymmetry between the extent to which IDMs customize their products and activities towards their customers and the extent to which customers customize their products and operations towards the IDMs. There is a much greater customization by IDMs towards their customers than by customers towards their IDM suppliers.

1 Fabless company data was garnered in an earlier industry study administered by Professor Rahul Kapoor in collaboration with the Global Semiconductor Alliance (GSA). The findings from that study were published in the report titled *Collaborative Innovation in the Global Semiconductor Industry: A Report on the Findings from the 2010 Wharton-GSA Semiconductor Ecosystem Survey*, which is available at www.gsaglobal.org/publications/whartongsastudy/.

IDMS' COMPLEMENTOR RELATIONSHIPS

- Many executives identified other semiconductor companies (ASIC / ASSP, analog, microprocessor, etc.) as their complementors. Complementors also included companies developing application software, programming software, and operating systems.
- About 71% of complementor relationships identified were managed through the IDMs' engineering department, with the remainder being managed through the marketing department.
- Generally, IDMs interact with their complementors more by sharing information on market applications and joint product development, followed by R&D plans and product customization. IDMs report less interaction through setting standards, joint marketing with their customers, licensing, and the least through investing in their complementors.
- Collaboration with complementors seems to have the highest impact on improving the performance of IDM companies' products, as well as acquiring new customers in both existing markets and new markets. The effect is somewhat lower for increasing sales to existing customers.
- There exists a high variance in the nature of collaborative relationships between IDMs and their complementors. However, more collaborative relationships are associated with greater value creation by IDM companies.

The findings shed light on a broad array of challenges and opportunities that IDM companies face within their ecosystem. In general, while the relationship with foundries is somewhat at an arm's length, a balanced manufacturing strategy seems to be paying off at least in the short term. Moreover, the importance of having internal manufacturing was reinforced not only in terms of having a high level of coordination between product design and manufacturing activities, but also having greater leverage over foundries. In assessing time-to-market drivers, it was clear that IDMs were typically faster to commercialize new product designs using existing manufacturing process than were fabless companies. However, given the scale and complexity of development activities associated with new manufacturing processes, IDMs were typically slower to push a new design through to market with a new manufacturing process.

The results reaffirmed that the ecosystem provides a rich set of opportunities for semiconductor companies to create value. However, while many companies have established extensive collaborative relationships with customers and complementors, there are many others that seem to be working at an arm's length, and perhaps not able to reap the full benefits from their ecosystem.

Survey findings also showed the important role played by complementors in enhancing the IDMs' competitive position. Complementors are often other semiconductor companies that develop complementary integrated circuits (ICs) used in the customer's application. However, managing relationships with complementors seems organizationally more complex. While there are well-defined departments for managing relationships with suppliers and customers, the relationship with complementors seems to be managed in very different ways, both within and across companies. Hence, in addition to suppliers and customers, IDM companies pursuing collaborative innovation models need to explicitly consider different types of complementors and develop organizational structures to effectively manage these new types of relationships.

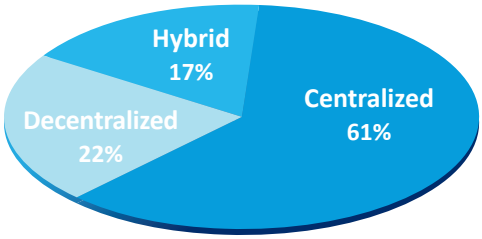
Survey results provide an in-depth view of the different sources of value creation that IDMs can leverage within their ecosystem while cautioning executives about the different trade-offs and conflicts that may exist within the ecosystem.

IDM Firms' Manufacturing Organization & Strategy

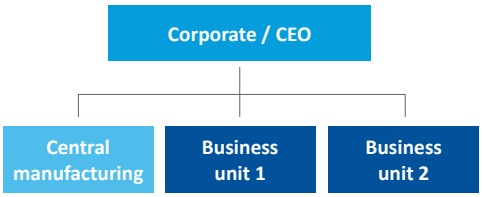
CORPORATE STRUCTURE

An important consideration for IDM companies is to design their organization, so they can effectively coordinate their manufacturing activities with their different business units and product lines. We asked survey respondents to identify the corporate structure that best described how the silicon manufacturing function is formally organized within their company (Figure 2). **The majority of companies in our sample (61%) use a centralized structure where manufacturing activities are organized at the corporate level. For 22% of surveyed companies, manufacturing activities are decentralized and organized within separate business units.** The remainder seems to be using a hybrid structure of centralized and decentralized manufacturing, perhaps dictated by the differences in the required specialization of manufacturing processes for their respective product lines.

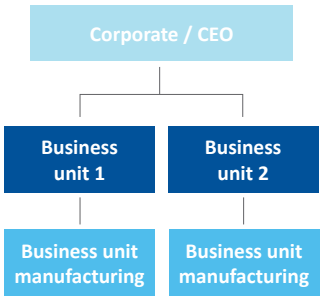
Figure 2: Corporate manufacturing structure of IDMs



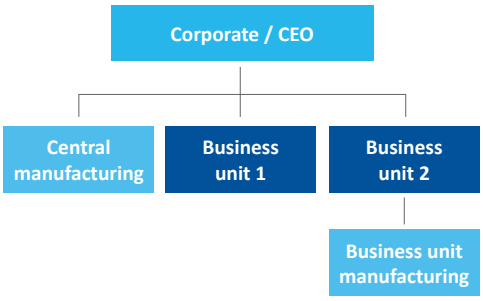
Centralized
No business unit has a manufacturing organization.



Decentralized
Business units have their own manufacturing organizations.



Hybrid
The corporate organization and some business units have their own manufacturing organizations.



IDM FIRMS LEVERAGING MARKETS (OUTSOURCING TO FOUNDRIES AND OFFERING FOUNDRY SERVICE)

Given the significant investments required to maintain manufacturing activities, an important strategic consideration for IDM companies is whether to outsource a proportion of their manufacturing to foundries, and perhaps also offer their manufacturing assets as a service to other semiconductor companies. 74% of surveyed IDM companies reported outsourcing at least 10% of their total silicon manufacturing to foundries while about 43% reported offering their internal silicon manufacturing capacity to other semiconductor companies. **Hence, IDM companies have moved to much more open business models to derive greater efficiencies from their internal assets.**

Figure 3: Does your company outsource more than 10% of its total silicon manufacturing?

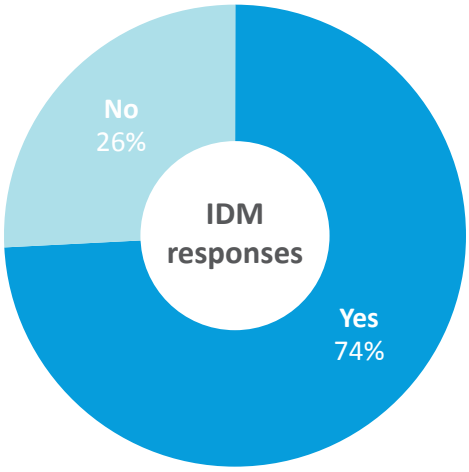
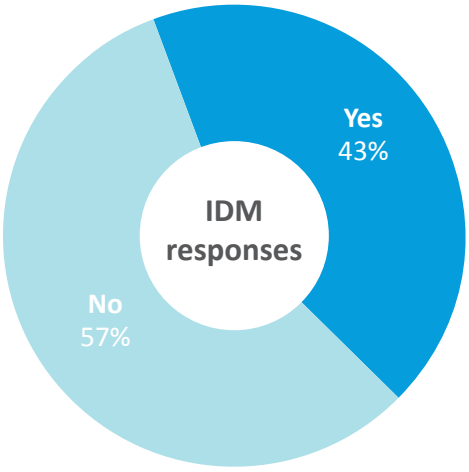


Figure 4: Does your company offer internal silicon manufacturing capacity to other companies?



Difference Between IDM & Fabless Companies

INTERNAL AND EXTERNAL MANUFACTURING RELATIONSHIPS

As IDM companies increasingly partner with foundries, it is important to understand how the nature of interactions among IDM companies differs between their internal manufacturing unit and external foundries. We evaluated this interaction in three different ways: **(1)** the extent to which suppliers share different types of information with IDM companies, **(2)** the extent to which suppliers are involved in companies' value-creating activities, and **(3)** the extent to which both companies and suppliers customize their activities towards each other. Only those IDM companies that indicated outsourcing at least 10% of their total silicon manufacturing to foundries were asked to provide their response for their relationships with foundries. Each survey participant had an option to provide their response for two different foundry companies in addition to their internal manufacturing unit.

Figure 5 illustrates the findings on information sharing. As expected, there is a very high degree of information sharing between the internal manufacturing unit and the business units. However, when compared to fabless companies, **on average, foundry suppliers seem to have a lower degree of information sharing with IDM companies, especially with respect to suppliers' cost structure, process monitoring, and proprietary technical information.** This finding may, in part, reflect the conflicts and the challenges that IDM companies face in working with both internal manufacturing units and external foundries.

Figure 5: Information sharing by foundry suppliers

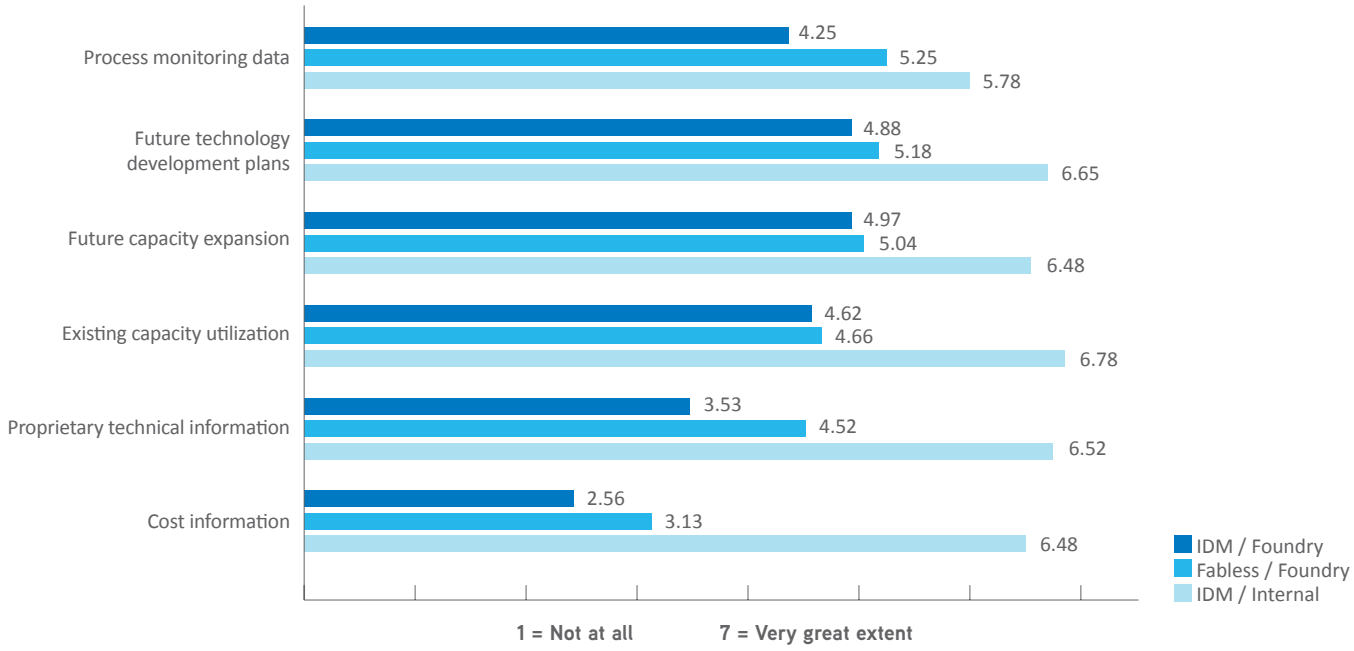


Figure 6 presents the findings on supplier involvement. In general, the internal manufacturing unit seems to be highly involved with many of the value-creating activities undertaken by the business units with the somewhat expected exception of system design. However, as was the case with information sharing, foundry companies were less involved in IDM firms' value-creating activities as compared to fabless companies. This was particularly the case for design and cost reduction activities. **Hence, it seems that foundries transact much more at an arm's length relationship with IDM companies than they do with fabless companies.** Or perhaps, the issue is that IDMs are not forced to rely on foundries as much as fabless companies, given the prominent role internal manufacturing still plays towards creating value.

Figure 6: Involvement by foundry suppliers towards value-creating activities

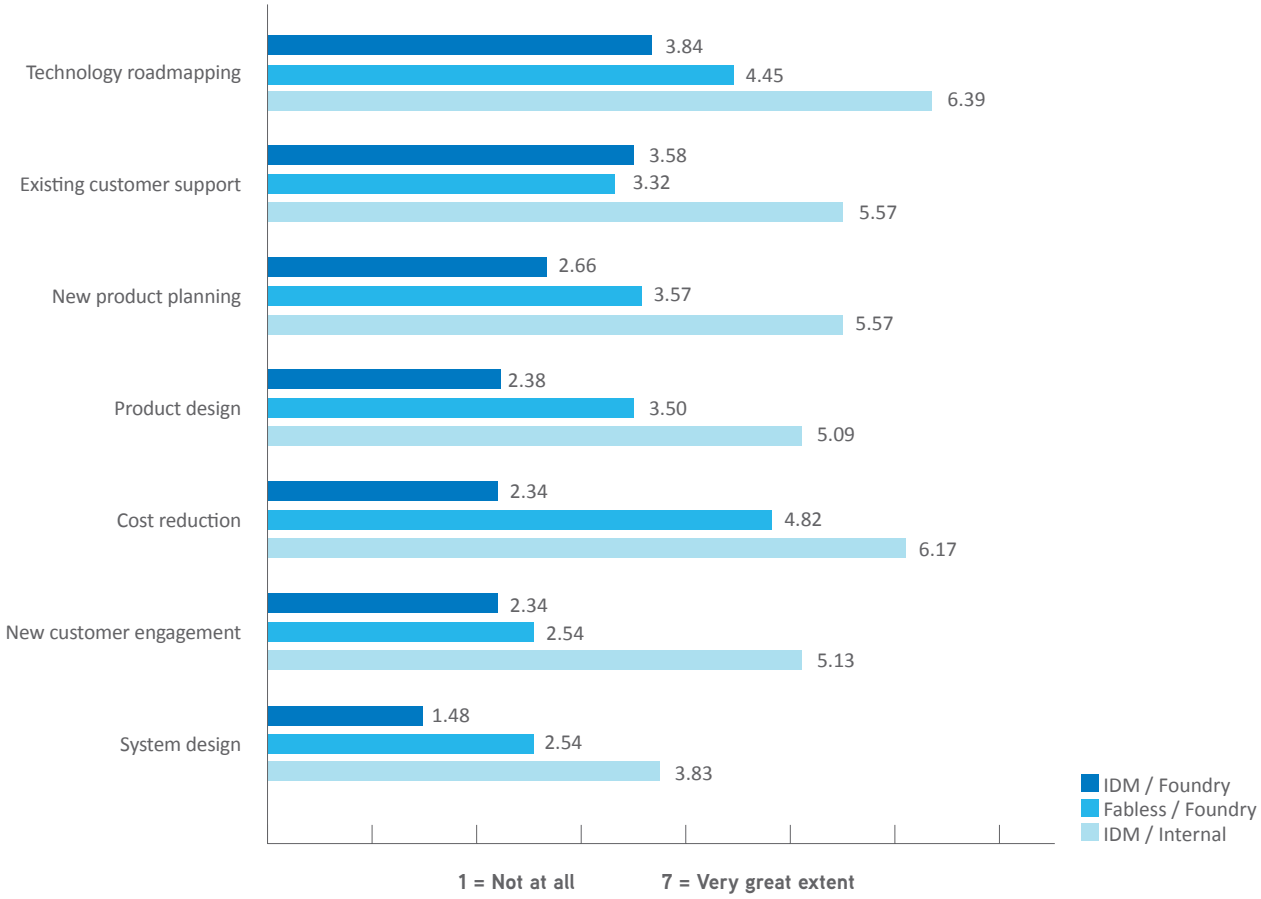


Figure 7a plots the extent to which IDMs' internal manufacturing activities and products are customized to each other. Figure 7b plots the extent to which IDM companies and foundry companies customize their activities towards each other. As expected, there is a much higher degree of customization between the internal manufacturing activities and the products of an IDM firm. Also, consistent with the patterns for information sharing and supplier involvement reported above, IDM companies do not seem to customize their products as much to a specific foundry's process as do fabless companies. **However, in sharp contrast, foundry companies seem to be customizing their processes and operations much more for IDM companies than for fabless companies.**

Figure 7a: Level of customization with respect to internal manufacturing activities

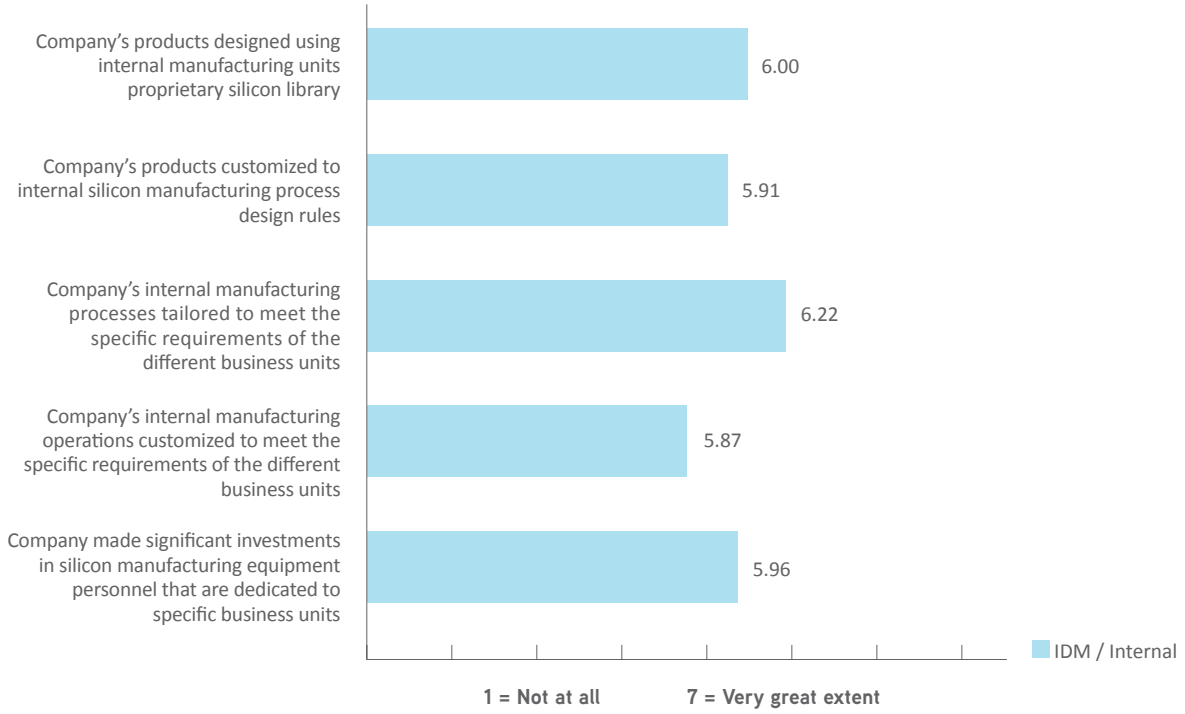
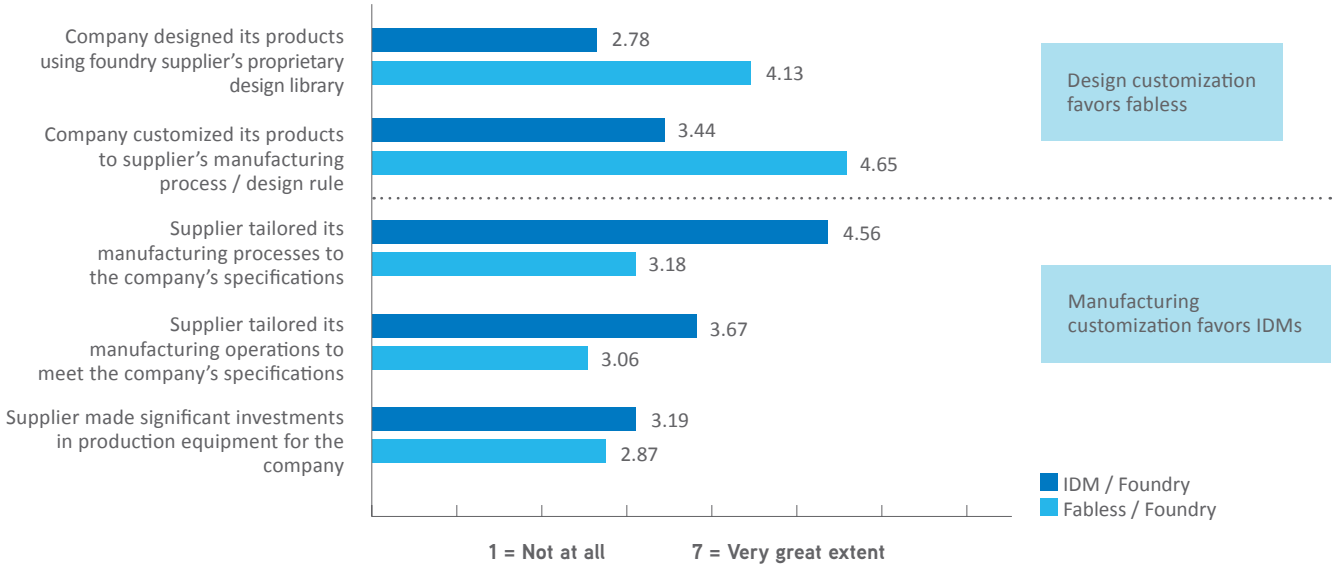
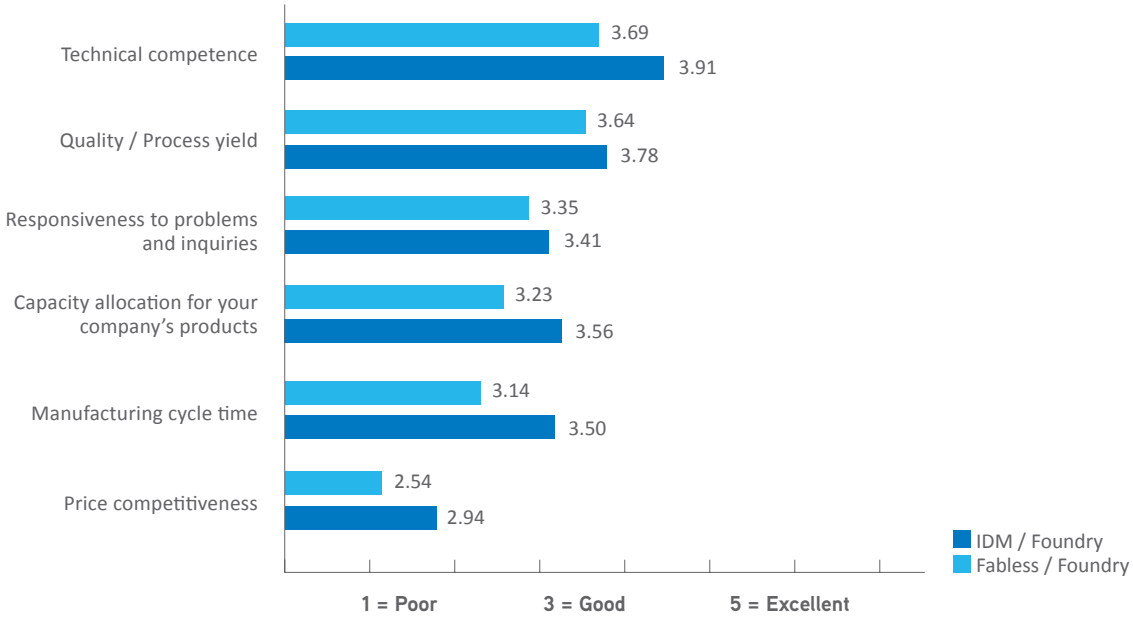


Figure 7b: Level of customization with respect to foundry suppliers



IDM and fabless companies generally perceive their foundries' performance to be good or very good with respect to the suppliers' technical competence, process quality, responsiveness to problems and inquiries, capacity allocation, and manufacturing cycle time (Figure 8). However, they seem less satisfied by the suppliers' price competitiveness. **Overall, IDM companies seem slightly more satisfied than fabless companies with their foundry suppliers.**

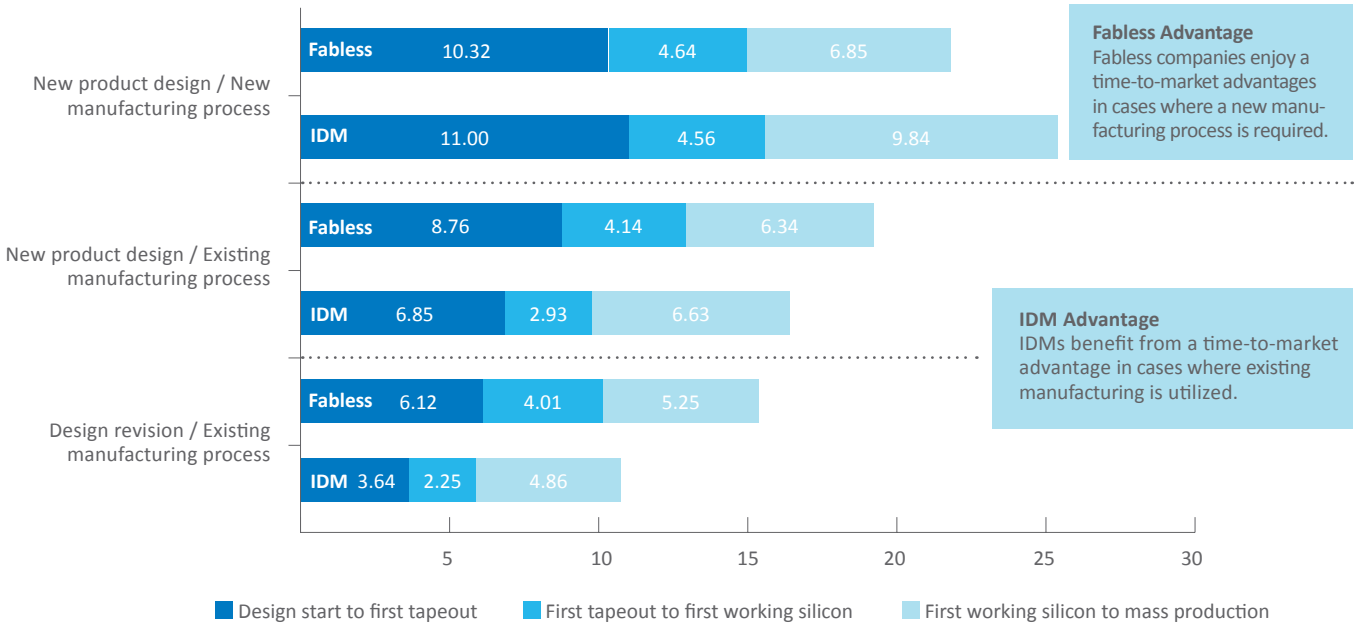
Figure 8: Perceived supplier performance



TIME-TO-MARKET MILESTONES

An important parameter for new product development activities is the company's time-to-market. In this study, time-to-market is defined as the period between the start of IC product design to the time when the product reaches mass production stage. Time-to-market is not only a critical source of competitive advantage for semiconductor companies, but also an important metric used to allocate resources and make strategic commitments. We asked survey respondents to provide an approximate time-to-completion for the three different stages that comprise a product's time-to-market: **(1)** design start to first tape-out, **(2)** first tape-out to first working silicon, and **(3)** first working silicon to mass production. To assess differences in timelines between different types of projects, we asked our respondents to provide information for three different projects based on whether product development was for a design revision or a new product design, and whether it was based on an existing manufacturing process that the company had used before or a new manufacturing process. Figure 9 reports on average values.

Figure 9: Time-to-market milestones (months)



For IDM companies, the average time-to-market is about 11 months for the revision of an existing product design. It increases to about 17 months for a new product design. A shift to a new manufacturing process increases time-to-market by about eight months.

- The average time from design start to first tape-out increases by about three months from pursuing a revision of an existing design to pursuing a new product design, and increases by about four months from using an existing manufacturing process to using a new manufacturing process.
- The average time from first tape-out to first working silicon increases by about a month from pursuing a revision of an existing design to pursuing a new product design, and increases by about two months from using an existing manufacturing process to using a new manufacturing process.

- The average time from first working silicon to mass production increases by about two months from pursuing a design revision to pursuing a new product design, and increases by about three months from using an existing manufacturing process to using a new manufacturing process.

On average, IDM companies seem to be faster in commercializing new product designs and design revisions using existing manufacturing process. This is mainly attributed to shorter time period between design start and first tape-out as well as between first tape-out and first working silicon. **Control over manufacturing activities appears to accelerate time-to-market when manufacturing requirements are relatively incremental. However, fabless companies appear to enjoy a time-to-market advantage in cases where a new manufacturing process is required. IDM firms take about three additional months to move from first working silicon to mass production. This longer time span may reflect the fact that IDM firms need to develop and scale up new processes whereas fabless firms leverage their foundries' existing manufacturing infrastructure.**

SOURCING AND LEVERAGING IP

Sourcing and leveraging IP is a critical driver of the dependence and competitiveness level of semiconductor companies. Fabless companies are on average dependent on foundries and third-party IP firms for 18% and 16% of their IP needs respectively. IDM companies are much more internally dependent, with foundries and third-party IP firms each representing on average only 8% of their total IP needs.

Figure 10: Sources of intellectual property

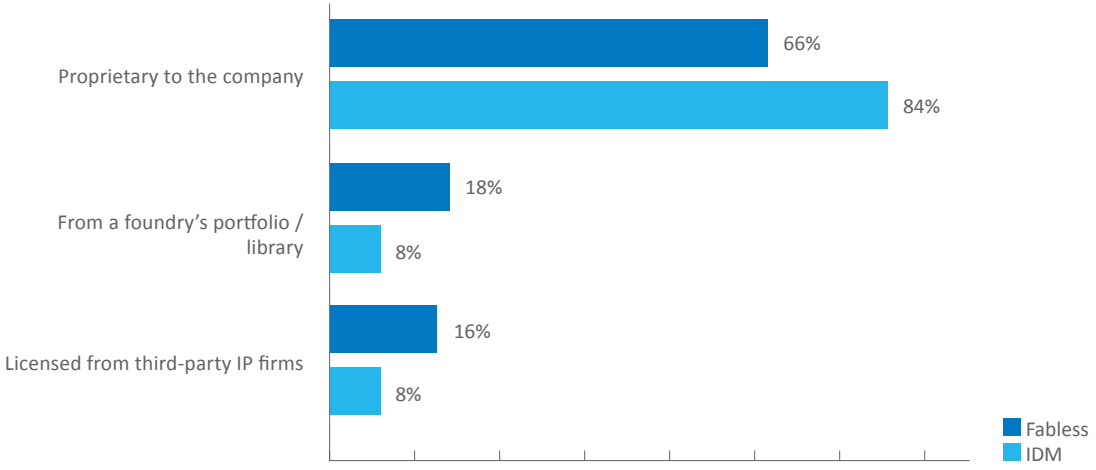
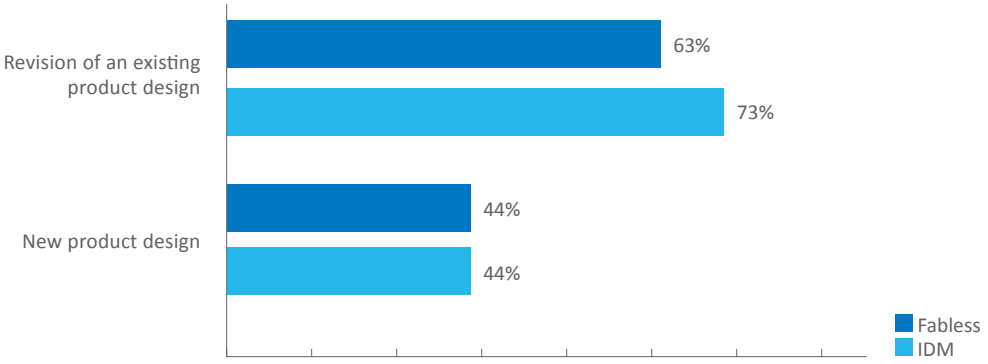


Figure 11 shows the extent to which semiconductor companies achieve economic efficiency by reusing existing design IP in new products. **On average, IDM companies reuse about 73% of their design IP in product design revisions, with this value going down to about 44% for new product designs.** Given that fabless companies have a relatively lower dependence on internal IP, they have a somewhat lower IP reuse in product design revisions.

Figure 11: Design IP reuse



Relationships Between IDM Firms & Their Customers

We evaluated the extent of collaboration between IDM companies and their customers in three different ways: **(1)** the extent to which customers share different types of information with IDMs, **(2)** the extent to which IDMs are involved in customers' value-creating activities, and **(3)** the extent to which both IDMs and customers tailor their activities towards each other. Each survey participant had the option to provide their response for two different customers.

Survey participants provided information on their relationships with customers from a variety of market segments, ranging from consumer and industrial electronics to wired and wireless communications, as well as industrial and automotive electronics.

Figure 12 illustrates the findings on the extent to which customers share different types of information with IDMs.On average, customers share extensive information on market trends as well as product development status and plans, but tend to be more tight-lipped around product cost and volume projections. Figure 13 shows the findings regarding the involvement of IDM companies in customers' product and technology development activities. On average, IDMs seem to be most involved in their customers' cost reduction and long-term technology roadmapping activities and less involved in underlying product development. **Hence, there seems to be a mismatch between information sharing and joint value creation. While IDMs are heavily involved in customers' product cost reduction activities, customers tend to be tight-lipped about actual product cost.**

Figure 12: Customer information sharing with IDMs

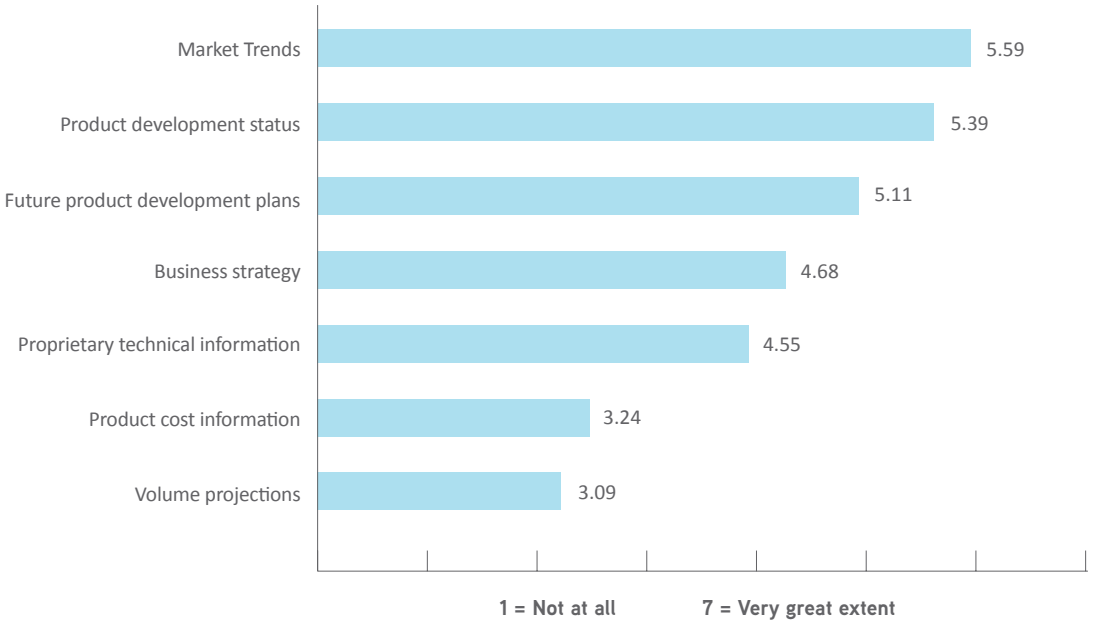


Figure 13: IDMs' involvement in customers' product and technology development activities

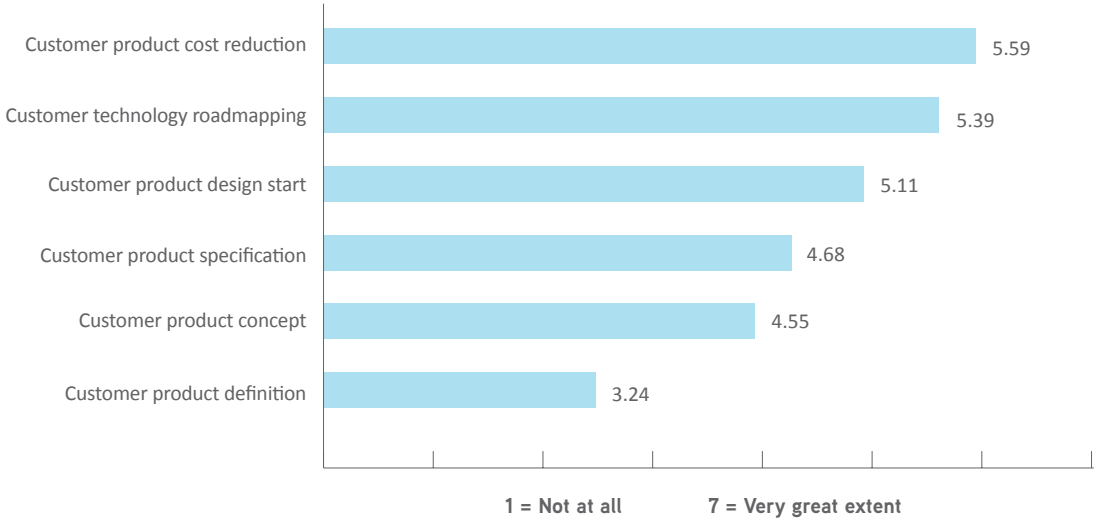
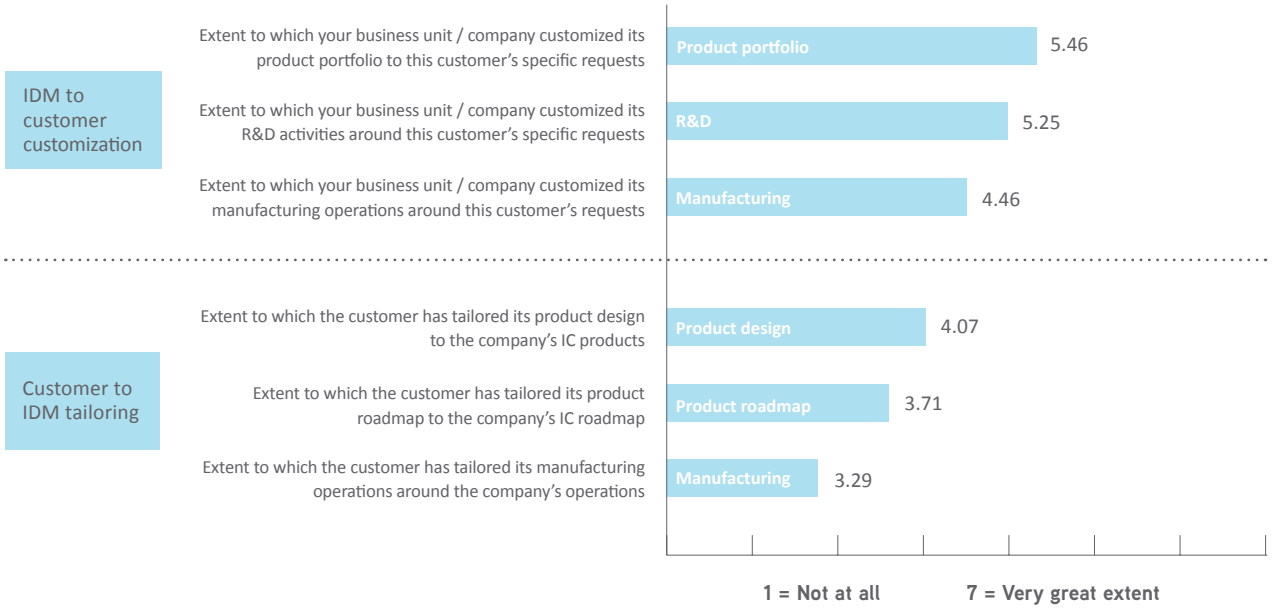


Figure 14 plots the response from IDMs regarding the extent to which they and their customers tailor their activities towards each other. In general, there is a significant asymmetry between the extent to which IDMs customize their products and activities towards their customers and the extent to which customers customize their products and operations towards IDMs. **There is greater customization by IDMs towards their customers than by customers towards their IDM suppliers.** This asymmetry could reflect the strategic choices made by IDMs to customize their products, R&D activities, and manufacturing operations around their customers' specific needs. However, customers may be less willing to depend on a specific supplier, and hence undertake a reduced level of tailoring.

Figure 14: Level of customization between IDMs and customers



Relationships Between IDM Firms & Complementors

Complementors, i.e. companies providing complementary products that are integrated in the customer's application, play an important role in the IDMs' ecosystem. For example, Intel and Microsoft are complementors in the PC market. The marketing and business development executives who participated in our study provided information on the nature of their company's collaboration with complementors. Many executives identified other semiconductor companies (ASIC / ASSP, analog, microprocessor, etc.) as their complementors. Complementors also included companies developing application software, programming software, and operating systems.

When asked about the department that was primarily responsible for managing the relationships with complementors, about 71% of complementor relationships identified were managed through the IDMs' engineering department, with the remainder being managed through the marketing department. **Hence, managing relationships with complementors may perhaps be organizationally more complex than managing relationships with suppliers or customers which tend to be managed by well-defined departments.**

Figure 15 shows the different ways by which IDMs collaborate with their complementors. **Generally, they interact with their complementors more by sharing information on market applications and joint product development, followed by R&D plans and product customization. IDMs report less interaction through setting standards, joint marketing with their customer, licensing, and the least through investing in their complementors.**

Figure 15: Means by which IDMs interact with complementors

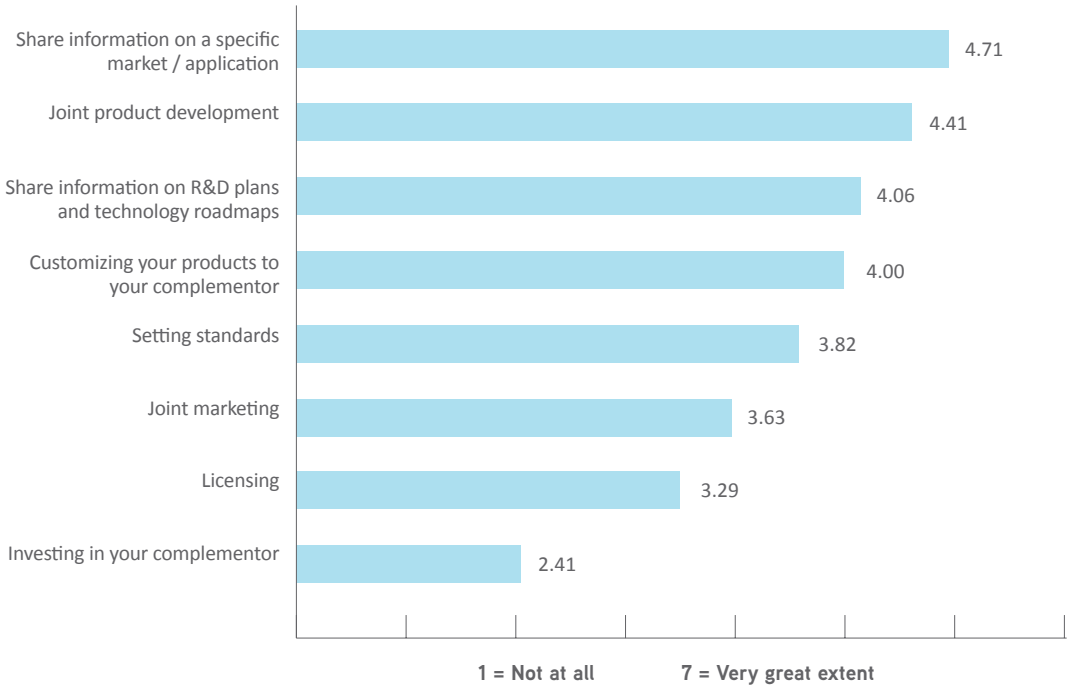
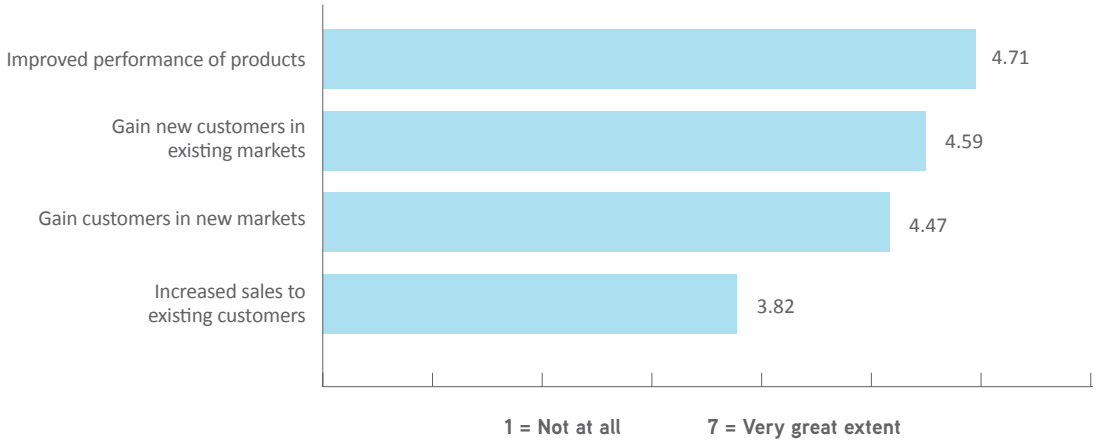


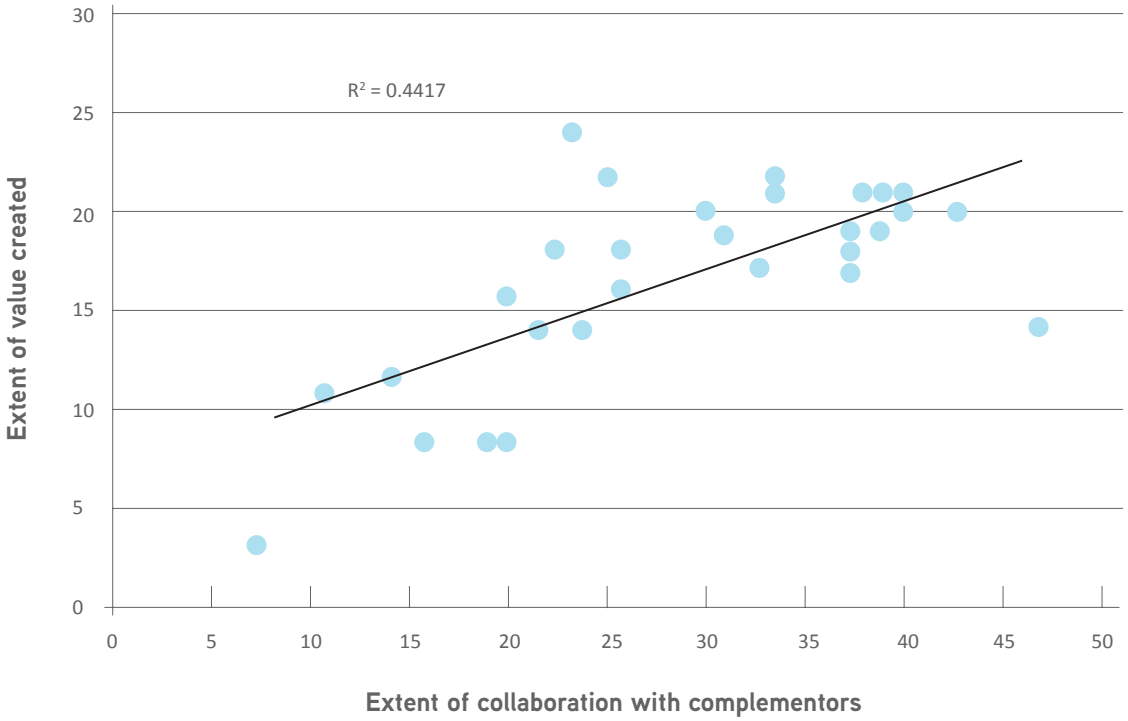
Figure 16 shows the different ways in which IDMs are able to create value from their complementor relationships. **On average, collaboration with complementors seems to have the highest impact on improving the performance of IDM companies' products, as well as acquiring new customers in both existing markets and new markets.** The effect seems to be somewhat lower for increasing sales to existing customers.

Figure 16: Types of benefits from IDM-complementor relationships



In exploring the link between the extent of collaborative complementor relationships and the benefit of such relationships, we plotted the sum of items for collaboration against the sum of items for value creation. Note that we excluded the investing in your complementor item from the collaboration score because it is not strictly a collaborative process and it was not an important mode of interaction reported by survey respondents. Figure 17 shows a significant positive correlation between the extent of collaboration between the IDM and the complementors and the extent of value creation. **Hence, having strong collaborative relationships with complementors seems to help IDM firms create greater value.**

Figure 17: Benefits of IDMs collaborating with complementors



Conclusion

We conducted the Wharton-ATREG Semiconductor Ecosystem Study to provide an extensive and systematic analysis of the different sources of value creation available to IDM companies within the semiconductor ecosystem and how they may interact with IDMs' business models and competitive strategies.

The findings shed light on a broad array of challenges and opportunities that IDMs face within their ecosystem. The results confirmed the ongoing trend of IDMs shifting towards fab-lite strategies by leveraging foundries for a significant portion of their manufacturing as well as offering their internal silicon manufacturing capacity to other companies. This shift is clearly driven by the need to generate economic efficiencies in the face of rising complexity and pace of change. However, as compared to the fabless-foundry relationship, the IDM-foundry relationship seems to be characterized by much more of an arm's length relationship with lower level of information sharing and involvement in IDMs' value-creating activities by foundry suppliers. This difference may be reflective of the conflicts and challenges that IDMs face in working simultaneously with both internal manufacturing units and external foundries. At the same time, this simultaneity also seems to provide some benefits to IDMs as foundries are much more likely to customize their manufacturing processes around the needs of their IDM customers.

The trade-offs between IDM and fabless models were also evident by the observed differences in the time-to-market. While IDMs are much faster to commercialize new designs on existing manufacturing processes, they seem on average slower to commercialize new designs on new manufacturing processes. This could reflect inherent differences in the extent of design manufacturing customization between fabless and IDM companies. The difference could also be due to the fact that fabless companies essentially contract for a newly available manufacturing process at the foundry whereas IDMs internally develop a new manufacturing process.

The survey results reaffirmed the importance of collaborating with customers and complementors in the ecosystem and at the same time, point to some important challenges. While close collaboration with customers is key to value creation, customers were in general less inclined to sharing sensitive information such as cost and volume projections, actively involving IDMs in their product development activities, and customizing their products and operations towards an IDM's technology and operations. A majority of respondents identified the important role played by complementors in enhancing an IDM's competitive position. These complementors are often other semiconductor companies that develop complementary ICs used in the customer's application. However, there was high variance in the extent to which firms collaborate with complementors. Moreover, managing relationships with complementors seems organizationally more complex. While there are well-defined departments for managing relationships with suppliers and customers, the relationship with complementors seems to be managed in very different ways both within and across companies.

Research Methodology & Demographics

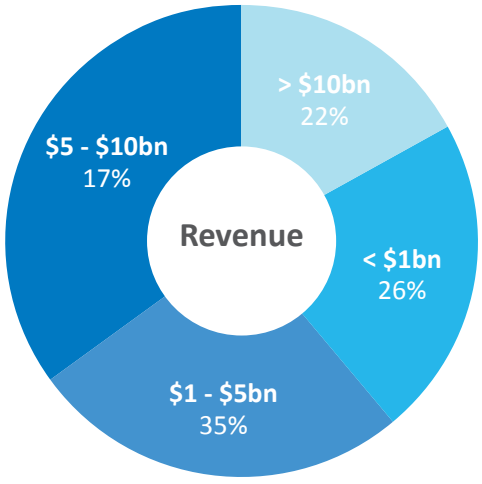
To ensure the survey findings' reliability and relevance to the industry, we followed a multi-step research approach. The first step entailed conducting a series of in-depth interviews with more than 50 executives from semiconductor companies, original equipment manufacturing (OEM) customers, foundries, assembly and test providers, as well as third-party IP suppliers. These interviews were aimed at helping us understand the nature of coordination and technical challenges that exist within the semiconductor ecosystem and guide the overall survey design. We then developed a detailed online survey consisting of three different sections—manufacturing, marketing, and product development.

Next, we pre-tested the survey with a number of executives whose feedback was used to refine the final survey that we then fielded through a secure web site.

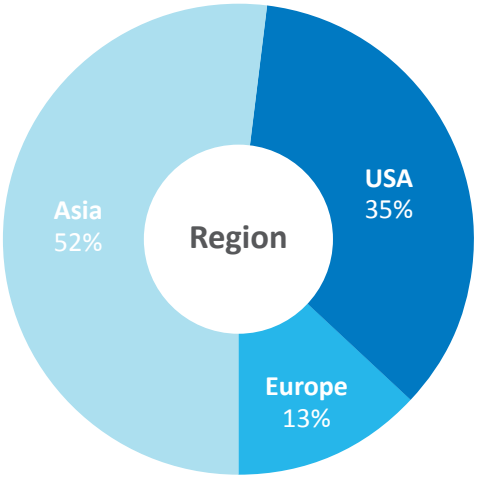
The findings featured in this report are based on detailed responses received from senior executives at 23 publicly listed integrated device manufacturers (IDMs), including 11 of the 20 largest IDMs based on 2011 annual revenue. The overall response rate to this industry study amounted to 40%. Figures 18 and 19 below respectively show the revenue and geographic distribution of participating sample companies.

Figure 18 & 19: IDM respondent distribution by revenue & geography

IDM respondent distribution by revenue



IDM respondent distribution by geography



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