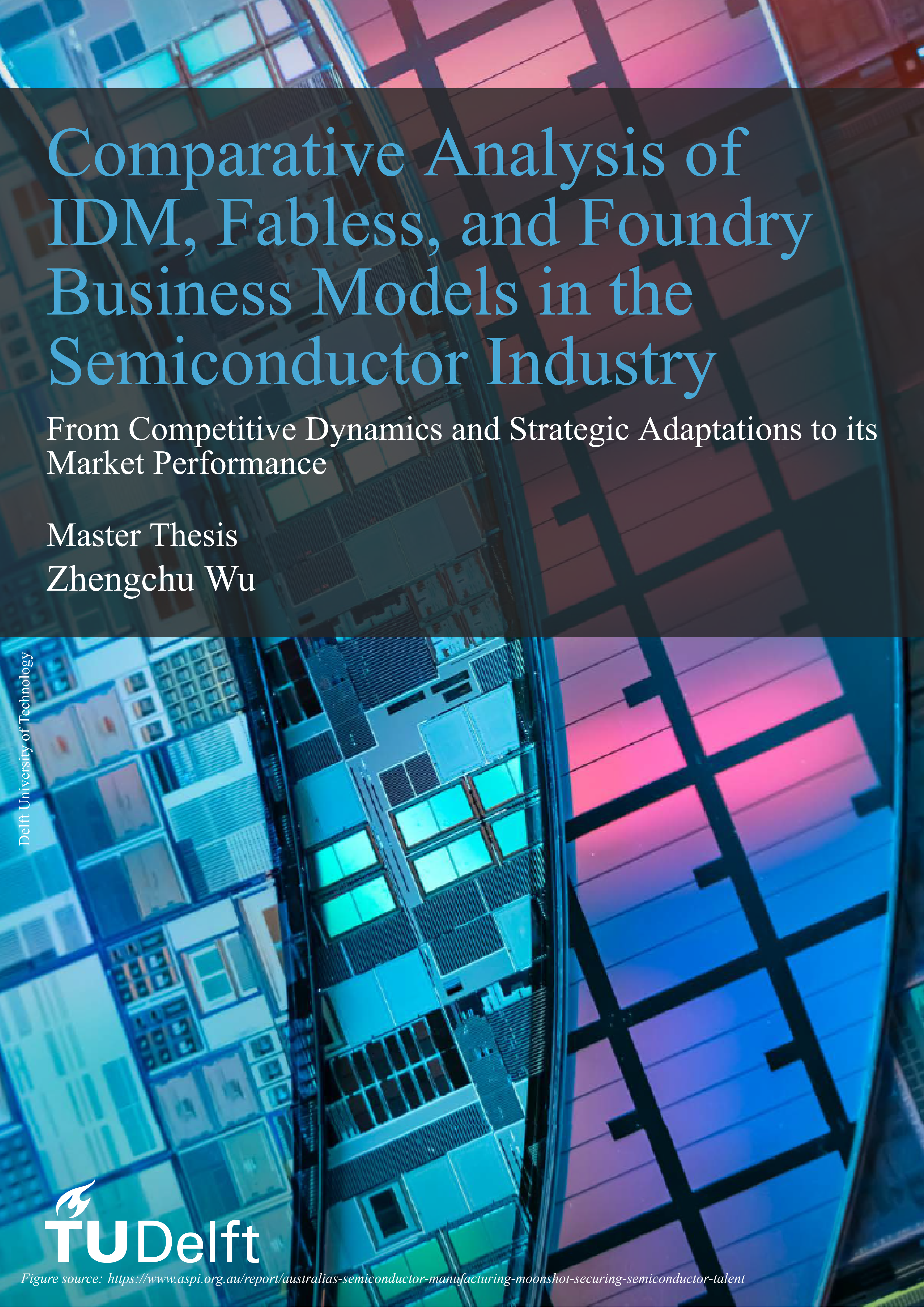

Comparative Analysis of IDM, Fabless, and Foundry Business Models in the Semiconductor Industry

From Competitive Dynamics and Strategic Adaptations to its Market Performance

Master Thesis

Zhengchu Wu

Delft University of Technology

Figure source: https://www.aspi.org.au/report/australias-semiconductor-manufacturing-moonshot-securing-semiconductor-talent

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MASTER OF SCIENCE
in Management of Technology

by

Zhengchu Wu
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To be defended in public on August 27, 2024

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Summary

The semiconductor industry, which has evolved over around 65 years, witnessed the emergence of the Integrated Device Manufacturer (IDM) business model, followed by the introduction of the fabless and foundry models. These three models continue to coexist and interact today. Characterised by cyclicality, capital and technology intensity, and high economic volatility, the semiconductor industry is shaped by the complicated interactions among these business models, which form the competitive dynamics of the industry. Companies must adopt strategic adaptations in response to these dynamics, further influencing their market performance. The relationship among competitive dynamics, strategic adaptations, and market performance is not a linear causal chain but a complex, mutually influential process. This study focuses on examining and comparing these concepts' relationships within the IDM, fabless, and foundry business models.

The main research question addressed by this study is: "What are the interactions among competitive dynamics, strategic adaptations, and market performance within IDM, fabless, and foundry business models in the semiconductor industry?" The study employs a triangulation methodology that includes a literature review, comparative analysis using the Business Model Canvas (BMC) and the C-STOF model, case studies of Intel, AMD, and TSMC using Eisenhardt's case study approach, and semi-structured thematic interviews with six semiconductor industry experts, analysed using the qualitative data analysis software ATLAS.ti. This combined methodology results in a series of propositions, which are initially proposed after each research method and subsequently integrated and validated to achieve the research objective and answer the research questions.

The literature review identifies knowledge gaps and provides detailed definitions of competitive dynamics and strategic adaptations, using three existing theories—Cyclical Model of Technological Change, Resource-Based View, and Dynamic Capabilities Framework—to clarify the theoretical linkages between these concepts. The comparative analysis serves to compare the features, commonalities, and differences among the three business models. The case studies extract insights from the development trajectories of three case companies, generalising these findings to the business model level to explore the relationships among competitive dynamics, strategic adaptations, and market performance. The interview thematic analysis integrates and validates these findings, forming the complete list of propositions.

The main findings of this study can be generalised at the methodological level, the enterprise level, and the industry level, extending and enhancing the theories mentioned. Theoretically, the study situates the semiconductor industry to the established theory frameworks and extends their relevancy. Regarding managerial implications, the study provides targeted recommendations for IDM, fabless, and foundry models and overall suggestions, offering practical references for academic researchers and industry practitioners. Additionally, the study discusses limitations related to data collection and processing, recognising areas for future research to enhance the generalizability and applicability of the findings.

Keywords: semiconductor industry, business models, IDM, fabless, foundry, competitive dynamics, strategies, market performance

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Zhengchu Wu
Delft, July 2024

Contents

Glossary

Abbreviations

Abbreviation	Definition
AIB	Add-In-Board
B2B	Business-to-Business
BMC	Business Model Canvas
CapEx	Capital Expenditure
COT	Customer Owned Tooling
CPU	Central Processing Unit
CRM	Customer Relationship Management
DRAM	Dynamic Random Access Memory
DTCO	Design Technology Co-Optimization
EDA	Electronic Design Automation
EUV	Extreme Ultraviolet
EMEA	Europe, Middle East, and Africa
ESG	Environmental, Social, and Governance
fab	Fabrication Plant
FPGA	Field-Programmable Gate Array
FSA	Fabless Semiconductor Alliance
GAA	Gate-All-Around
HHI	Herfindahl-Hirschman Index
HPC	High-Performance Computing
IC	Integrated Circuit
ICT	Information and Communication Technology
IDM	Integrated Device Manufacturer
InFO	Integrated Fan-Out
IoT	Internet of Things
IPC	Instruction Per Clock
IP	Intellectual Property
LSI	Large-Scale Integration
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
OEM	Original Equipment Manufacturer
OpEx	Operational Expenditure
OSAT	Outsourced Semiconductor Assembly and Test
PC	Personal Computer
RBV	Resource-Based View
ROI	Return on Investment
RTL	Register-Transfer Level
SRAM	Static Random Access Memory
SoC	System on Chip
TCO	Total Cost of Ownership
ULSI	Ultra-Large-Scale Integration
VLSI	Very-Large-Scale Integration
VRIN	Valuable, Rare, Inimitable, and Non-substitutable

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1 Introduction

1.1. Research background

The semiconductor industry refers to a range of companies specializing in designing and producing semiconductors and related devices, such as transistors and integrated circuits (IC). The semiconductor materials, such as silicon, germanium, and gallium arsenide, defined by their electrical conductivity between conductors and insulators at room temperature, are indispensable to modern electronics. They constitute critical components of numerous electronic devices, including computers, smartphones, and digital recorders.

The semiconductor industry was initially formed around 1960 when the production of semiconductor devices became commercially feasible (Langlois & Steinmueller, 1999). By 2018, the annual sales revenue of the industry exceeded $481 billion, marking significant and impressive growth since its inception (G. Chen, 2019). The semiconductor industry is characterized by its extreme capital and technology intensity, along with high economic volatility and inherent risks (B.-G. Chang & Wu, 2021). However, the semiconductor industry is increasingly acknowledged as a significant technological catalyst and a central driver within the broader electronics value chain (B.-N. Hwang et al., 2008).

Currently, the semiconductor industry is predominantly comprised of three major business models: Integrated Device Manufacturers (IDMs), which manage a complete production process covering design, manufacturing, packaging, and testing, e.g. Intel and Samsung; fabless companies, which specialize in semiconductor design rather than the manufacturing process, e.g. Qualcomm, NVIDIA and IBM; and foundries, in contrast to IDM, are dedicated solely to semiconductor fabrication, focusing on chip processing and manufacturing as represented by TSMC. The detailed context of these business models is elaborated in section 3.2.

Influenced by its high capital and technology intensity and rapid iteration characteristics, the semiconductor industry is inherently competitive and ever-changing. Within this dynamic environment, companies strive to survive by consciously undertaking strategic adaptations, whether proactively or reactively (K. G. Smith et al., 2005). These strategic adaptations include, but are not limited to, adjustments, mergers and acquisitions, collaborations and even complete transformations (Schindehutte & Morris, 2001). Such strategic initiatives further impact the market performance of these companies, which may, in turn, influence the competitive posture of the industry. The detailed argument of the relationship between these two concepts can be found in section 3.5. Market performance, a series of critical indicators in determining the success of semiconductor companies, further drives the strategic adaptations undertaken by these firms, perpetuating a cyclical influence on the industry's competitive posture. The interplay among competitive dynamics, strategic adaptations, and market performance is not a linear cause-and-effect chain but a complex process of mutual interaction. This study focuses on examining how these business models can maintain competitiveness and resilience in the face of competitive dynamics and strategic adaptations and enhance their market performance.

1.2. Problem statement and knowledge gap

IDMs, fabless, and foundry models represent the core business structures within the current semiconductor industry. These models differ fundamentally in their operational strategies, resource allocations, and responses to market and technological shifts. While existing literature (Hung et al., 2017; Y.-T. Li et al., 2014; Sarma & Sun, 2017; Wang & Lin, 2021) provides insights into the individual characteristics and challenges faced by each business model in the semiconductor industry, there remains an apparent absence of research that integrates these aspects into a holistic view. Specifically, current academic discourse has yet to thoroughly explore the impacts of the interplay between competitive dynamics and the strategic adaptations to the final market performance among IDMs, fabless, and foundry models. Considering these models' critical role in shaping the global semiconductor structure, influencing innovation trajectories, and dictating industry resilience (Kim & Cho, 2023), this gap is worth exploring.

The study by Hung et al. (2017) exhaustively employed the Lotka-Volterra model to examine the competitive and cooperative relationships among the semiconductor industry's three main business models (IDM, fabless, and foundry) and forecasted their market shares. However, given the context of rapidly evolving semiconductor technologies and a complex industry structure, the strategic directions adopted by firms within different business models can significantly influence their roles in the industry and, consequently, their market performance. The research by C. Lin et al. (2020) takes the semiconductor industry as a case example to construct a performance evaluation framework applicable to companies, utilizing Miles et al. (1978)'s typology to explore differences in competitive performance and the utility and effectiveness of strategies. The study focuses on objective ways to engage in the strategic planning process. It offers a method for identifying a firm's strategy typology based on financial and functional performance data, assisting top management in strategy comparison and decision-making. However, the gap is reflected in the lack of exploration of the dynamic interactions from the perspective of different business models within the semiconductor industry.

Nonetheless, this study aims to conduct a comparative analysis of the three predominant business models in the semiconductor industry to fill the gap in the literature that compares the core differences, respective features, advantages, disadvantages and common or distinct strategic responses to the competitive dynamics, between these business models. Rather than providing a mere snapshot of the current industry landscape, this research seeks to propose several propositions. By focusing on propositions that elaborate the relationship between competitive dynamics, strategic adaptations, and market performance, this study intends to enrich the understanding of the semiconductor industry. Besides, these propositions could help explore the extent to which competitive dynamics among different business models influence strategic adaptations, and how specific strategic decisions or adjustments can affect the market standing of a given business model. The findings of this study could offer insights to investors within the semiconductor sector, as well as inspire top-level executives in their strategic decision-making processes.

1.3. Research objective and research questions

The primary objective of this research is to conduct a comparative analysis of the major business models and case studies for specific companies for each business model and integrate insights from experts through interviews in the semiconductor industry – IDMs, foundries, and fabless companies. This study examines the interplay between competitive dynamics, strategic adaptations and market performance in the face of rapid technological advancements and market shifts. Explicitly, the research will explore the competitive situations formed by how these business models differ, interact, compete, and collaborate within the evolving semiconductor industry, that impacting their strategies and overall market performance.

1.3.1. Research questions

The main research question can be summarized as follows:

'What is the interplay between competitive dynamics, strategic adaptations and the market performance of IDM, fabless, and foundry business models in the semiconductor industry?'

1.3.2. Sub-questions

A series of sub-questions are formulated and will be sequentially examined, thereby methodically contributing to the comprehensive answer to the main research question.

Sub-question 1

What are the essential differences between IDM, foundry and fabless business models?

This sub-question addresses the need for a detailed comparative analysis of the three business models, providing a fundamental understanding of their distinct characteristics and core differences.

Sub-question 2

How do competitive dynamics relate to strategic adaptations in the semiconductor industry?

This sub-question aims first to clarify what the study refers to as competitive dynamics and strategic adaptation in the semiconductor industry and explore the relationship between them to provide a theoretical basis for the subsequent analysis. These concepts and connections are an area that is not fully explored in the existing literature (e.g., the work of Hung et al. (2017)).

Sub-question 3

How do the competitive dynamics mutually influence the strategic adaptations of the three business models within the semiconductor industry?

This sub-question seeks to understand the bidirectional influence between competitive dynamics and strategic adaptations among different business models, addressing the gaps in current research (e.g., Y.-T. Li et al. (2014), Sarma and Sun (2017), and Wang and Lin (2021)) that focus on individual business models but does not explore the interconnections between these concepts.

Sub-question 4

How do the results of the interaction further influence the market performance of the business model?

This sub-question focuses on examining how the interactions between competitive dynamics and strategic adaptations impact the market performance of the business models. It aims to investigate the consequential effects of these interactions on the industry's complex interplay of competitive landscape and strategic initiatives within enterprises. By addressing this, the sub-question seeks to fill the final component of the identified knowledge gap and contribute to the significance of the overall research.

Approaches to sub-questions

SQ1 will be answered through a series of propositions proposed in the comparative analysis by respectively studying three business models using the Business Model Canvas (BMC) and the three selected representative companies using the C-STOF model analysis. Specifically, BMC is used to examine the following four orientations of a company or business model: supply or resource orientation, value orientation, demand orientation, and financial orientation. The C-STOF model analysis is adopted for detailed examination of internal aspects of an individual company, which includes customer values, services, technologies, organizations, and finances. The combination of BMC and C-STOF could offer a holistic view of business models by enhancing the breadth and depth of the analysis. It could also provide practical and strategic insights by integrating empirical findings from specific case companies. The concepts of competitive dynamics and strategic adaptation in the semiconductor industry will first be clarified, and the correlation and theoretical linkages between these two concepts will be illustrated in the literature review to answer SQ2. SQ3 focuses on case studies using Eisenhardt's case study approach, and this step aims to analyse the interactive process of competitive dynamics, strategic adaptation, and market performance of the three selected case companies through detailed within-case studies and cross-case studies. Eventually, the SQ1, SQ2, and SQ3 results will be merged with the qualitative data from literature research and results from interview thematic analysis to adjust the propositions, and then answer the SQ4.

1.4. Research outline

The structure of this thesis report, as depicted in the accompanying Figure 1.1, is primarily divided into three main sections.

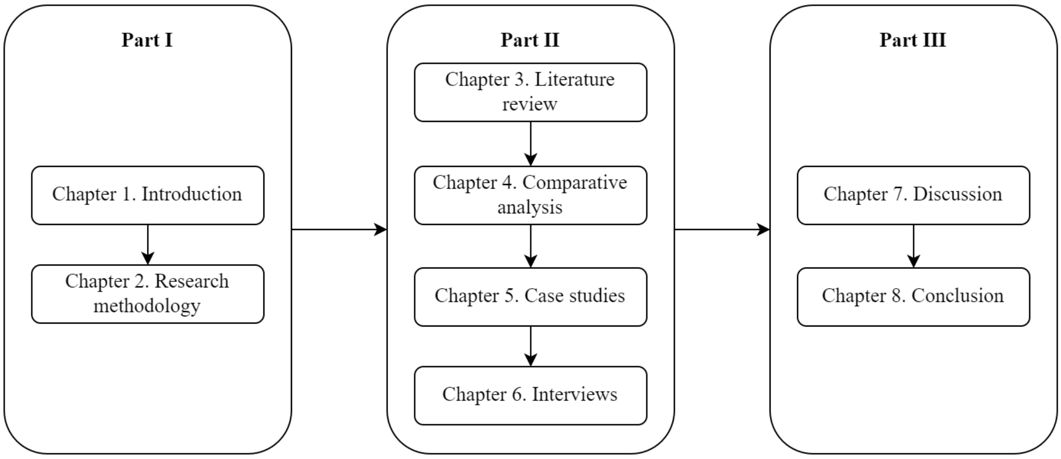

Figure 1.1: Thesis outline

The first section begins with Chapter 1, which provides a detailed introduction to the research background. This includes an overview of the development history of the semiconductor industry, a brief introduction of the three major business models, and definitions of key concepts such as competitive dynamics and strategic adaptation. Additionally, this chapter outlines the problem statement, identifies knowledge gaps, and delineates the research objectives and questions. Chapter 2 illustrates the detailed and specific research methodologies employed to address the research questions, along with their sequential application.

Chapter 3 presents a comprehensive literature review, establishing the foundation for subsequent research and identifying gaps in the existing body of knowledge. Additionally, the literature review is served as part of the qualitative data source. The specific purpose of the literature review will be described in detail in section 2.1. Chapter 4 uses the Business Model Canvas method and C-STOF model to compare and analyze the three major business models and case companies within the semiconductor industry. Chapter 5 provides case studies of three selected semiconductor companies, each representing one of the three business models, including within-case studies and cross-case studies. Chapter 6 demonstrates the integration of interview insights from six semiconductor industry experts, serving as the data analysis and triangulation for Chapters 4 and 5. The complete version of the proposition list will also be presented. The triangulation part will be explained in Section 2.

Finally, Chapters 7 and 8 are dedicated to the discussion and conclusion of the research results, comprised of answers to the research questions, generalizability, limitation, and managerial and theoretical contributions of the research.

2

Research methodology

This chapter elaborates on the research methodology adopted in this study, which is structured to address the research questions systematically. The qualitative analysis is carried out throughout the methodology, comprising a literature review, comparative analysis, secondary data analysis of case studies, and interviews. As depicted in Figure 2.1, the roadmap of the research process highlights the specific steps undertaken and the corresponding research questions addressed at each stage.

The initial data collection step includes an extensive literature review focusing on several areas: semiconductor business models (IDM, fabless, foundry), the historical and contemporary evolution of the semiconductor industry, and the dynamics of competition and strategic adaptations within the sector. This literature review establishes a theoretical foundation and identifies potential linkages between the various concepts. Qualitative data regarding case studies is collected from the official company website, the company's annual report, professional semiconductor association report, credible technological journal and financial website. Insights from semiconductor industry experts are collected through semi-structured interviews, which are recorded and transcribed for analysis.

The subsequent data analysis step adopted methodological triangulation, which consists of qualitative data from literature review, interviews, comparative analysis and case studies. Triangulation aims to cross-validate insights derived from the literature review, comparative analysis, case studies, and semi-structured interviews to ensure the accuracy and pertinence of the research outcome. The data collected in the literature review is subjected to the proposition development of comparative analysis using the Business Model Canvas (BMC) and C-STOF model method and the discussion of the theoretical linkages between competitive dynamics and strategic adaptation in the semiconductor industry. These stages involve formulating several propositions regarding business models and the abovementioned concepts. Data collected from companies is first analyzed through detailed within-case studies and, afterwards, cross-case studies. This stage also includes proposition development concerning the mutual influence of competitive dynamics, strategic adaptations and market performance of each business model. Insights derived from the interviews serve as both data sources and triangulated validation of previous propositions. These propositions are eventually refined, modified and enhanced based on the integrated analysis results.

The final step synthesizes the overall analysis and addresses the main research question posed by the study, specifically including a summary of key findings, compiling a complete list of propositions, and discussing the generalizability, contributions and limitations of this study.

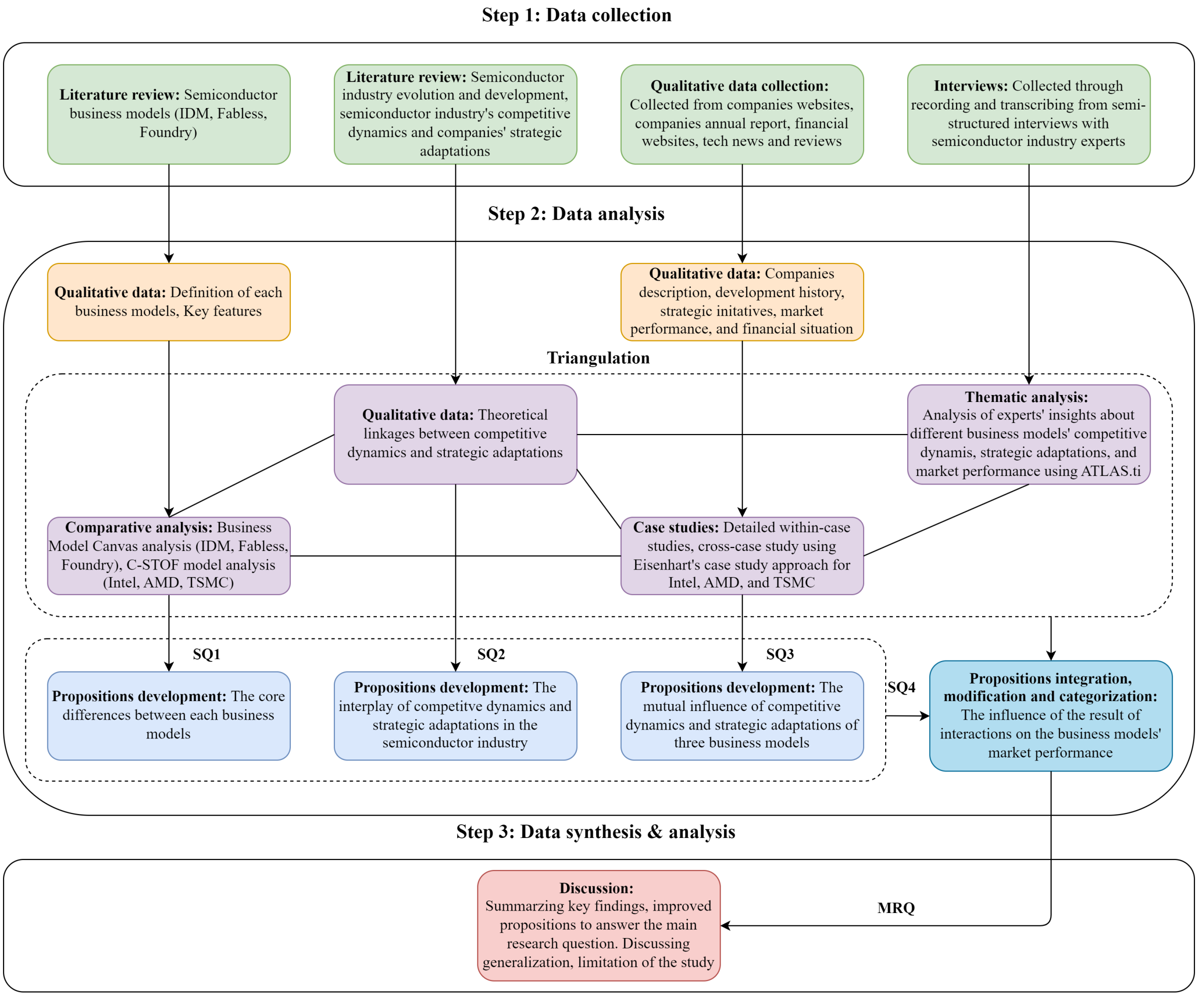

Figure 2.1: Research methodology

2.1. Data collection

This study's data collection methodology is anchored in a comprehensive literature review, qualitative data collection from secondary sources, and semi-structured interviews with industry experts. The aim of the literature review is to ascertain the current state of the semiconductor industry and establish the case study subjects—Intel, AMD, and TSMC- for their respective reasons. The main research question has been divided into four sub-questions: qualitative data, comparative analysis, case studies and insights from interviews drawn to address sub-questions.

2.1.1. Literature review

Step 1: Literature identification

A set of criteria for inclusion and exclusion was put into place. The literature review set out by such a filter reflected the areas of crucial interest: the iterative development of business models in the semiconductor industry, interactions of business models, the business models present in a competitive environment in the industry, and strategic management practices of the semiconductor firm.

Step 2: Literature search

Some of the academic search engines used are Google Scholar, ScienceDirect, JSTOR, ResearchGate, and IEEE Xplore. The quality and reliability of the papers are identified based on the level and number of citations. Specific keywords were identified in terms of the search and their abbreviations and synonyms used in various combinations, such as 'IDM strategic management,' 'fabless and foundry collaboration model,' 'semiconductor business model interaction,’ ’semiconductor industry competitive dynamics,’ and ’semiconductor enterprise strategy.’ After the literature search, approximately 40 relevant documents were obtained, which mainly focused on the detailed elaboration of a single semiconductor business model, the interaction between business models, competition and cooperation, and the overall strategic level of the industry.

Step 3: Literature screening

Each paper’s abstract, introduction, and conclusion were read upon screening the retrieved literature. The inclusion and exclusion criteria were applied to the initial screened literature. For instance, the literature that focused on elements in the semiconductor industry, which is irrelevant to this research, was excluded, e.g., detailed supply chain research and geopolitical impacts on the semiconductor industry. Another example would be the literature regarding the case study of a specific company from IDM or fabless or foundry model, which was also excluded. Only those research studies that partly overlap with this research’s objectives in the semiconductor industry are included. After screening, the most relevant studies were identified, which could be used for further reading. Thus, the final reference list comprised of 32 references was formed.

2.1.2. Qualitative data for case studies and comparative analysis

Data type

Qualitative data is collected from various credible secondary sources for BMC analysis and C-STOF model analysis, within-case studies and cross-case analysis, which includes:

- **Companies’ websites and annual reports:**
  These sources provide complete information on company operations, structures, features, financial performance, strategic initiatives, and technological advancements.
- **Professional semiconductor association reports:**
  These reports offer insights into industry-wide trends, benchmarks, and competitive landscape analyses.
- **Technological journals and financial websites:**
  These publications include in-depth articles, market analyses, financial data, and expert opinions on the semiconductor industry.

The data gathered from these sources incorporated with qualitative data from the literature review supports the BMC and C-STOF model method in the comparative analysis and subsequent within-case and cross-case studies in the case study.

Data source list

Table 2.1: Data sources for comparative analysis, C-STOF model, and case studies

Methodology	Source	Specific report/year
Comparative analysis	Asia Pacific Journal of Management	The genesis of fabless business model: Institutional entrepreneurs in an adaptive ecosystem (2017)
	Brookings Trade Forum	Offshoring in the Semiconductor Industry: A Historical Perspective (2005)
	Center for Strategic and International Studies (CSIS)	Mapping the Semiconductor Supply Chain: The Critical Role of the Indo-Pacific Region (2023)
	Darcy & Roy Press	IDM Innovation: A Case Study of Intel’s Acquisition of Tower Semiconductor (2023)
	Harvard Business School	Horizontal Specialization and Modularity in the Semiconductor Industry (2008)
	Harvard Business School	Technical, organizational and business model modularity: Evidence from the fabless semiconductor industry (2021)

Methodology	Source	Specific report/year
	IEEE Xplore	Analysis of Competition Between IDM and Fabless–Foundry Business Models in the Semiconductor Industry (2017)
	IEEE Xplore	EUV Lithography: State-of-the-Art Review (2019)
	IEEE Xplore	Fabless Semiconductor Implementation Model as an Enabling Factor for ”Virtual Labs” in Online Postgraduate Degrees in Microelectronics (2018)
	IEEE Xplore	Global Semiconductor Industry Trend—IDM Versus Foundry Approaches [Point of View] (2009)
	IEEE Xplore	Semiconductor Supply Chain Planning With Decisions of Decoupling Point and VMI Scenario (2017)
	IEEE Xplore	The study on identifying the required competences in the emerging fabless IC design service industry (2010)
	Journal of Microelectronic Manufacturing	EUV Lithography: State-of-the-Art Review (2019)
	Semiconductor Digest	Intel Launches ‘IDM 2.0’ Strategy, Including Two New U.S. Fabs and Foundry Services (2021)
	Semiconductor Industry Association (SIA)	Strengthening the Global Semiconductor Supply Chain in an Uncertain Era (2021)
	Small Business Economics	Entry and innovation: an analysis of the fabless semiconductor business (2011)
	Sustainability	Fabless Semiconductor Firms’ Financial Performance Determinant Factors: Product Platform Efficiency and Technological Capability (2018)
	Technology in Society	Partnership ecosystem of IC design service companies: The case of Taiwan (2015)
	Wharton School & ATREG	Managing Complexity & Change in the Semiconductor Ecosystem (2012)
Case Intel	Gartner	Intel semiconductor market revenue share worldwide from 2008 to 2023
	Gartner	Semiconductor companies market revenue share worldwide from 2008 to 2023
	Intel Corporate Social Responsibility Report	2023-2024
	Intel Corporation Annual Report	2014, 2021, 2022
	Intel Official Website	-
	NasdaqGS collated by Finbox	Capital expenditures for Intel Corporation, 2024
	NasdaqGS collated by MarcoTrends	Intel EBIT/operating expenses/ROI/Revenue/Net income/Net profit margin history from 2010-2023
	NasdaqGS collated by MarketWatch	INTC stock price | Intel Corp. Stock Quote
	NasdaqGS collated by YCharts	Intel revenue (annual) 2023
	TechInsights	The 2022 McLean Report
Case AMD	AMD Official Website	-

Methodology	Source	Specific report/year
	Creative Commons	Reinventing High Performance Computing: Challenges and Opportunities (2022)
	EE Times	Athlon sales drive AMD to record quarter (2000)
	IEEE Xplore	Pioneering Chiplet Technology and Design for the AMD EPYC™ and Ryzen™ Processor Families : Industrial Product (2021)
	NasdaqGS collated by MarcoTrends	AMD EBIT/operating expenses/ROI/Revenue/Net income/Net profit margin history from 2010 to 2023
	NasdaqGS collated by MarketWatch	AMD cash flow statement 2024
	PassMark Software	Passmark 2017 q1 desktop cpu market share report (2020)
	The Wall Street Journal	Amd charges toward $300 billion valuation (2024)
Case TSMC	Interos	G7 confronts China's designs on semiconductor supply chain
	NasdaqGS collated by MarcoTrends	TSMC EBIT/operating expenses/ROI/Revenue/Net income/Net profit margin history from 2010-2023
	Statista	Net income of Taiwan Semiconductor Manufacturing Company from 2015 to 2023 (in billion New Taiwan dollars)
	TrendForce	Semiconductor foundries revenue share worldwide from 2019 to 2023, by quarter
	TSMC Annual Report	2021, 2022, 2023
	TSMC Corporate Social Responsibility Report	2012
	TSMC Official Website	-
	TSMC Quarterly Management Report	2023Q4
	TSMC Sustainability Report	2022
	NVIDIA	Best of GPU Technology Conference (GTC) 2024 Spring Highlight

2.1.3. Interview data collection

The semi-structured interviews are conducted with six semiconductor industry experts to enhance the credibility of the research findings. The semi-structured interview method was chosen due to its comprehensive coverage of multidimensional factual practices and representation data and an effective method for data collection and triangulation (Albaret & Deas, 2023). The interview questions were developed methodically, with the primary objective of addressing the research sub-questions. These questions were designed to elicit detailed insights into the participants' professional experiences, their perceptions of industry trends, and the strategic decisions within their respective companies. The semi-structured format allowed for flexibility, enabling the interviewees to explore relevant issues in greater depth, thus enriching the data collection process.

Interview criteria

These experts were strictly selected according to the following interview criteria Table 2.2 to represent diverse perspectives from the three major business models within the semiconductor industry: IDMs, fabless companies, and foundries. Specifically, the interviewees comprised two experts from IDMs, two from fabless companies, and two from foundries. The selection aimed to ensure a thorough understanding of the competitive dynamics, strategic adaptations, and market performance across different business models.

Table 2.2: Interviewee selection criteria

Criteria	Description	Rationale
Industry expertise	Minimum of 5 years of experience in the semiconductor industry or demonstrated extensive managerial knowledge and expertise	Ensures broad managerial knowledge and understanding of semiconductor industry dynamics, trends and strategic initiatives of semiconductor company
Business model representation	Representatives from IDM, fabless, foundry	Provides diverse perspectives and insights to the comparative analysis
Position and role	Senior management positions such as CEOs, CTOs, CFOs, or Heads of Strategy/Operations	Ensures macro insights into competitive dynamics of the industry-level and strategic adaptations of the enterprise-level
Geographical representation	Flexible focus on interviewees from both the Netherlands and other regions	Leverages the LinkedIn connections to find qualified interviewees, which includes experts within the Netherlands, the geographical scope is not restricted to this region alone

2.1.4. Interview protocol

The interview protocol for this study was developed to ensure the collection of high-quality, relevant data to address the research questions. This protocol is designed to align with the criteria for selecting qualified experts and the methodological rigour required for academic research.

Interview questions

A complete set of interview questions was developed, containing the following categories:

- **General questions:** To understand the interviewee's background, their company's role and experience in the semiconductor industry.
- **Business model questions:** Tailored to the specific business model of the interviewee (IDM, fabless, or foundry). For instance, IDM-related questions were only asked to those interviewees from IDMs.
- **Competitive dynamics questions:** Focusing on the competitive landscape and how companies navigate this, including giving examples.
- **Strategic adaptations questions:** Exploring how companies adapt their strategies in response to market changes, includes giving examples.
- **Market performance questions:** Assessing the impact of competitive dynamics and strategic adaptations on market performance by giving specific metrics.

These questions were designed to directly address the main research question and sub-questions, while allowing for flexibility in the semi-structured interview format. This flexibility included asking additional questions if the interviewee's company had plans to expand into other business models, skipping questions that had already been answered and making detailed inquiries about some novel ideas that related to the research proposed by the interviewee.

Interview procedure

All interviews were conducted via Microsoft Teams due to geographical limitations. To ensure the reliability of the results, the interview procedure was standardized across all sessions. The steps included inviting participants, preparing for the interview, obtaining recording permissions, explaining the study, taking notes, and processing data post-interview. This consistent approach ensured that the data collected was reliable and valid. The following steps outline the interview procedure:

- **Invitation:** Potential interviewees were invited through a formal message explaining the study and the reason for their inclusion based on their background and role.
- **Scheduling and preparation:** An interview schedule was set upon acceptance, and a Microsoft Teams link was sent. Background research on both the firm and the respondent was conducted to refine the interview questions.
- **Informed consent:** The interview protocol was approved by the Human Research Ethics Committee (HREC), and each interviewee signed an informed consent form before participating.
- **Permission to record:** At the start of the interview, explicit permission to record the session was obtained.
- **Introduction:** The interviewer introduced themselves and provided an overview of the research, reiterating the interview's goals.
- **Note-taking and recording:** While the Microsoft Teams transcription function recorded the conversation, additional notes were taken to capture key points and follow-up questions.
- **Respect and objectivity:** The interviewer maintained a respectful and neutral stance, avoiding leading questions to ensure the objectivity of the responses.
- **Post-interview processing:** The recordings were transcribed within 48 hours. Any transcription errors were corrected by cross-referencing with the audio recordings. The final transcripts were in English.

The list of interview questions and referred transcriptions can be found in the Appendix B.1.

Ethical considerations

Ethical considerations were a priority throughout the interview process. Approval from the HREC commission was obtained, and informed consent was secured from all participants. The confidentiality and anonymity of the interviewees were maintained, and the data was handled according to ethical guidelines and processed with an approved data management plan.

2.2. Data analysis

The data analysis process comprises four key areas of qualitative data: features of the business model, definitions and theoretical linkages of competitive dynamics and strategic adaptation, the company's development history, strategic initiatives and financial information utilized in the case study, and expert insights from interviews. The methodological triangulation is adopted in this research as it mitigates the shortcomings and research bias associated with relying on a single research method. Qualitative data on business models are employed for comparative analysis, while company-specific data are used for case analysis. These two datasets are then triangulated with the aforementioned qualitative data.

Initially, the definition and theoretical linkages of competitive dynamics and strategic adaptations are stated according to the qualitative data that originated in the literature review. Subsequently, the BMC method is used for comparative analysis to establish a broad understanding of the general characteristics, strategies, and structures of IDM, fabless, and foundry business models. The aim is to provide an overview of the principal differences and similarities between these three business models in the semiconductor industry. The BMC developed by Alexander Osterwalder and Yves Pigneur could provide a clear structure to examine the external aspects of business models by focusing on the value proposition and its emphasis on customer interactions (Haaker et al., 2018). The C-STOF model method is also applied in the comparative analysis to examine the three selected semiconductor case companies. As articulated by Heikkilä et al. (2008), the C-STOF model offers a complete view through which to assess the internal mechanisms and strategic alignments of business models, including detailed metrics for quantifiable assessment. The above-mentioned methods are combined to formulate propositions and address the first two sub-questions. The detailed reasons for simultaneously adopting the BMC and C-STOF model methods will be explained in the section 2.2.1.

The case studies in the next step focus on an examination of individual companies using Eisenhart's case study approach to answer the third sub-question, including detailed within-case studies and cross-studies of Intel, AMD and TSMC, which represent IDM, fabless and foundry business models. Several propositions are derived regarding competitive dynamics, strategic adaptations and market performance of the three business models from the case studies. The expert insights from interviews serve not only as a data source but also as a means of triangulated validation. This validation process integrates, modifies, and categorizes the propositions derived from other methods to answer the fourth sub-question. The final data synthesis and analysis are conducted in the discussion section to address the main research question.

2.2.1. Comparative analysis

Data for comparative analysis is collected from an exhaustive literature review, industry-specific reports, and analysis of strategic decisions documented in reputable business journals and news. BMC and the C-STOF model are used as analytical methods to conduct the comparative analysis. The BMC and C-STOF analysis are complementary, as they focus on different aspects of business models; the former emphasizes the external level, while the latter focuses on internal elements. The purpose of concurrently employing both methods is to provide a macro perspective on business models using the BMC method. Following this, the C-STOF model allows for a deeper analysis of specific business models at the company level and also serves as a transition to the following case studies. This approach enables a deductive comparison, demonstrating how the differences and characteristics identified from the macro business model perspective are reflected and manifested at the individual level. Therefore, the integration of these two methods offers a holistic perspective on business models.

Business Model Canvas method

The BMC method, which involves comparative units of business models of IDMs, foundries, and fabless, evaluation metrics of 4 orientations and 9 key criteria: supply and resources-oriented (key partners, key activities, key resources), value-oriented (value proposition), demand-oriented (customer relationships, channels, customer segments), and financial oriented (cost structure, and revenue streams), as seen in the following conceptual Table 2.3.

Table 2.3: Conceptual Business Model Canvas table of IDM, fabless, and foundry

Orientations	Criteria	IDM	Fabless	Foundry
Supply and resources-oriented	Key partners	-	-	-
	Key activities	-	-	-
	Key resources	-	-	-
Value-oriented	Value proposition	-	-	-
Demand-Oriented	Customer relationships	-	-	-
	Channels	-	-	-
	Customer segments	-	-	-
Financial-oriented	Cost structure	-	-	-
	Revenue streams	-	-	-

The expected results comprise the proposal of several propositions regarding commonalities, differences, and patterns of different business models of these 9 criteria. These propositions are categorized by the four orientations: supply and resource-oriented, value-oriented, demand-oriented, and financial-oriented.

C-STOF model analysis

Before the case studies, the C-STOF analysis is employed for the three selected semiconductor companies due to its focus on the internal aspects of an enterprise. The selected companies are Intel for IDM, AMD for fabless, and TSMC for foundry. The original and complete C-STOF Model analysis proposed by Heikkilä et al. (2008) is presented in Table A.1 in the Appendix A.1.

Given that this study focuses on examining competitive dynamics, strategic adaptation, and market performance of business models within the semiconductor industry, overly detailed internal indicators related to specific companies are streamlined and excluded in the C-STOF analysis. The Table 2.4 presents the customized C-STOF model analysis, reflecting this tailored approach.

Table 2.4: Customized C-STOF model analysis

Criteria	Description
Customer value (C)	C1. Created customer value: Focus on unique value propositions, user experience, perceived customer benefit, and brand image. C2. Market segment and market share: Emphasize market reach, customer loyalty, and sales growth.
Service (S)	S1. Service development life cycles: Include development time of new service concepts and time to the first proposal. S2. Quality: Focus on product/service performance, reliability, and delivery time. S3. Sustainability & satisfaction: Include customer retention and churn rates.
Technology (T)	T1. Architectural complexity: Focus on architecture-related indicators and platform-related metrics. T2. Interoperability: Metrics of interoperability of systems.
Organization (O)	O1. Number of internal partners: Number of units and departments, roles and responsibilities. O2. Access to resources: Access to business networks and expertise flexibility.
Finance (F)	F1. Profitability: Key financial metrics like ROI, EBIT, net profit, and revenue growth. F2. Costs: Total expenses, CAPEX, OPEX, and cost efficiency.

This analysis acts as a bridge between the comparative analysis and the case study, providing foundational data that supports examining the case company in the following case studies and leading the case study's direction and focus.

2.2.2. Case studies

Within-case and cross-case studies

The within-case studies of Intel, representing the IDM model; TSMC, exemplifying the foundry model; and AMD, representing the fabless model, are conducted firstly to analyse these companies' detailed backgrounds and developments, common decision-making processes, competitive actions, and strategic adjustments.

The case study methodology as described by Eisenhardt (1989) is used in this study as its focus is to explore the interaction between competitive dynamics, strategic adaptation, and market performance among IDM, foundry, and fabless business models in the semiconductor industry. Eisenhardt's methodology excels in building new theories from case studies using empirical evidence. Given that the objective of this study is to propose and refine propositions based on case study findings, Eisenhardt's framework offers an effective approach to theory development from data.

Furthermore, this study includes three representative companies with different business models for case studies. Eisenhardt's methodology advocates for the use of multiple case studies to understand phenomena in diverse contexts and to facilitate cross-case analysis. This approach aligns well with the goals of this study by enabling a detailed examination of the various business models within the semiconductor industry. The following are the detailed case studies steps taken using Eisenhardt's approach.

- **Getting started:** Including defining research questions and conducting a thorough literature review to establish the foundational constructs.
- **Selecting cases:** Choosing cases that are theoretically useful and representative of each business model in the semiconductor industry as the sampling step during the literature review. Intel, AMD, and TSMC were selected for this study as they exemplify the IDM, fabless, and foundry business models, respectively.

- **Crafting instruments and protocols:** Collecting data from company reports, industry publications, and market analysis by using various data collection methods, as defined in the section 2.1, to analyze company operations, market strategies, and performance data.
- **Entering the field:** Gathering data while being flexible to availability while ensuring the reliability of the collected data.
- **Analyzing data:** Conducting detailed within-case analysis of each case individually. Perform cross-case analysis by comparing and examining the interactions of Intel, AMD, and TSMC to synthesize findings.
- **Shaping propositions:** Proposing initial propositions based on pattern recognition within the data.
- **Enfolding literature:** Triangulating findings with literature review, comparative analysis results and interview insights to validate and refine propositions.
- **Reaching closure:** Summarizing and finalizing the set of propositions based on the case studies.

The structured case study approach, including within-case analysis, and cross-case analysis, assists in understanding the competitive dynamics, strategic adaptations, and market performance from the perspective of individual companies within the semiconductor industry. The propositions developed in the case studies are categorized according to their topic to make a clear view of the proposition list.

2.2.3. Interview data analysis

This section utilizes the qualitative data analysis software ATLAS.ti to analyze interview data systematically. The software excels in coding and interpreting interview transcripts. It could promote time-saving and easier management of interview data from the practical perspective and enable the transparency and replicability of the analysis process to improve credibility from the empirical perspective (S. Hwang, 2008). Since the interview results are part of a triangulation methodology, they serve as both a data source and a validation step for conclusions and propositions derived from the literature review, comparative analysis, and case study.

All interviews, previously recorded and transcribed via Microsoft Teams, are imported into ATLAS.ti. Each transcript is categorized based on the respondent's business model representation (IDM, fabless, foundry) to maintain organizational clarity. The coding process involves assigning labels to text segments representing meaningful information units, thereby identifying key themes and patterns related to competitive dynamics, strategic adaptation, and market performance. Codes are divided into various categories reflecting the core research questions and subquestions. This includes general questions, specific business model questions, competitive dynamics, strategic adaptation, and market performance. Later, thematic analysis is facilitated by aggregating and comparing coded data across different interviews. Finally, the consistency and differences between interview data and previous findings are strictly reviewed to refine and validate the overall conclusions. The referred interview quotations can be found in Appendix B.2.

2.3. Data synthesis & analysis

This step focuses on data synthesis and analysis, the ultimate step that integrates findings from multiple sources to provide comprehensive insights into the research questions. This step is detailed in the Section 7, encompassing several key components:

Summarizing key findings

The synthesis begins by consolidating the key findings from the triangulation process, which includes:

- **Comparative Analysis:** Insights derived from the BMC and C-STOF model analysis applied to IDM, fabless, and foundry business models.
- **Case Studies:** Detailed examination of within-case and cross-case analysis of Intel, AMD, and TSMC.
- **Qualitative Data from Literature Review:** Theoretical linkages and realistic correlation of competitive dynamics and strategic adaptations identified through extensive literature review.
- **Interview Data:** Transcribed, coded, and analyzed qualitative data from expert interviews, processed using ATLAS.ti.

Propositions confirmation

This step involves refining and modifying the initial set of propositions based on the integrated analysis. The final set of propositions revolves around the following topics which are related to the main research question and sub-questions, as stated in section 1.3.2:

- Differences between IDM, fabless, and foundry business models in the semiconductor industry.
- Competitive dynamics and how they shape strategic adaptations within each business model.
- The impact of strategic adaptations on the market performance of these business models.

The answers to research questions, generalizability, theoretical and managerial contributions, limitations, and recommendations are also given in the Discussion section, which could offer reliable and actionable insights for industry stakeholders and academia by integrating multiple data sources and perspectives.

3

Literature review

This chapter begins with an overview of the semiconductor industry, tracing its historical context and current state and introducing its core driving factor - technological advancements. Subsequently, the origins and characteristics of the three primary business models within the industry are explained. A review of the existing literature on the competitive dynamics, strategic adaptations, and market performance in the semiconductor sector is presented, identifying current research gaps and the case subjects for the case studies. Additionally, this literature review serves as a data source of insights related to the research topic, collating significant findings from previous studies. The chapter also argues the concepts of competitive dynamics and strategic adaptations with established theoretical frameworks, e.g., the cyclical model of technological changes, resource-based views, and dynamics capabilities framework.

3.1. Overview of the semiconductor industry

3.1.1. Historical context

The origin of semiconductors can be traced back to the invention of the point-contact transistor by W. Brattain and J. Bardeen at Bell Laboratories at the end of 1947 (Holbrook et al., 2000). This led to the theoretical invention of the junction transistor by W. B. Shockley 38 days later, on January 23, 1948, as the most technically important solid-state device, and its formal invention on June 23, 1948, thus triggering the semiconductor revolution (Bondyopadhyay, 1998; Holbrook et al., 2000). In 1958, the first integrated circuit (IC) was demonstrated by Texas Instruments in the United States. The following year, the invention of the bipolar IC was achieved, wherein multiple devices were fabricated on a single silicon substrate and connected through wire bonding (Łukasiak & Jakubowski, 2010). These advancements marked the beginning of the IC era. The industry of semiconductors was initially formed around 1960 when the production of semiconductor devices became commercially feasible (Langlois & Steinmueller, 1999). As the integration of ICs continued to advance, this period saw the emergence of major players like Intel, founded by Noyce and Gordon Moore, which introduced the world's first microprocessor in 1971, fundamentally changing the computing landscape (Malone, 2014). The Very-Large-Scale Integration (VLSI) was developed in the 1980s, which incorporated between 100,000 to 10 million electronic components per chip. In the 1990s, this was further expanded with the advent of Ultra-Large-Scale Integration (ULSI), integrating over 10 million electronic components per chip. By the 2000s, multifunctional Large-Scale Integration (LSI), which integrated multiple functions into a single chip, had entered full-scale production. In the intelligent era, driven by the dual forces of consumer demand and technological advancements, the rise of 5G, AI, big data, cloud technology, and the Internet of Things (IoT) has further refined industrial specialization. Consequently, ICs are evolving towards higher performance and multifunctionality. By 2018, the annual sales revenue of the industry exceeded $481 billion, marking significant and impressive growth since its inception (G. Chen, 2019).

3.1.2. Current state

Semiconductor technology, serving as the cornerstone of modern electronic devices, finds extensive applications across various industries and domains. Its primary application areas encompass consumer electronics, communication equipment, computing and data centres, automotive electronics, industrial automation, and artificial intelligence. According to McKinsey's 2022 Semiconductor Practice report by Burkacky, Dragon, and Lehmann

(2022), the global semiconductor industry is poised for a decade of significant growth, with projections indicating it could evolve into a multi-trillion-dollar industry by 2030, as shown in Figure 3.1. Approximately 70% of this growth is anticipated to be propelled by three key industries: automotive, computing and data storage, and wireless communication. In 2023, the emergence of generative artificial intelligence triggered a global surge of interest, intensifying competition for large-scale models. By 2024, advancements in artificial intelligence are projected to enhance further chip computing power, storage performance, and energy efficiency, thereby fostering innovation in semiconductor architecture and advanced packaging, and driving the new market growth.

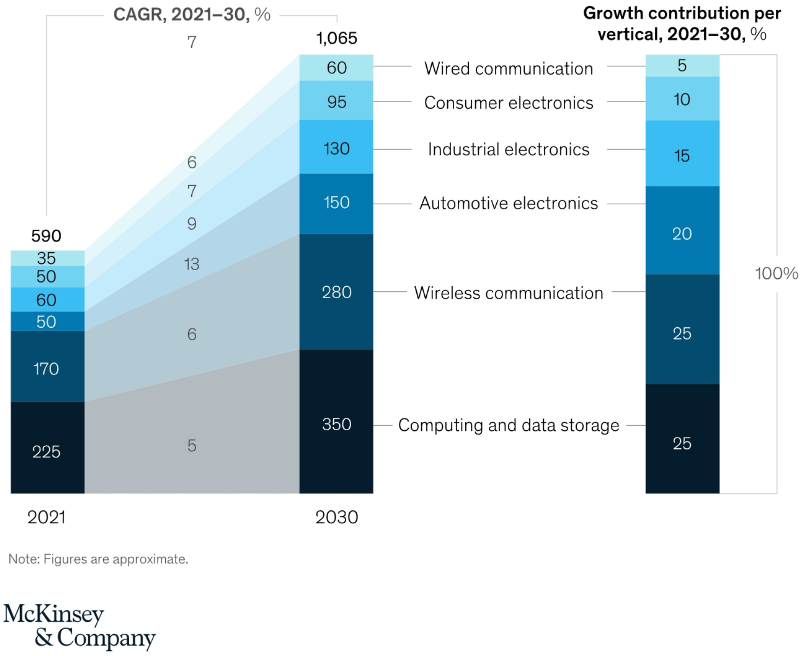

Figure 3.1: Global semiconductor market value by vertical, indicative, $ billion, Burkacky, Dragon, and Lehmann (2022, p. 3)

The distinct natures of industry are capital- and technology-intensive, with high economic volatility and associated risks (B.-G. Chang & Wu, 2021). The semiconductor industry encountered significant disruptions during the early stages of the COVID-19 pandemic in 2020. Interruptions in global supply chains led to chip production and transportation challenges, compelling many semiconductor manufacturers to temporarily shut down factories or reduce their production capacity. Nevertheless, driven by the surge in the stay-at-home economy, the semiconductor sector swiftly rebounded. Despite substantial short-term challenges imposed by macroeconomic headwinds, these temporary setbacks did not alter the industry's fundamental growth drivers (Casanova, 2023). These drivers are anticipated to regain their influence, fostering sustained long-term growth. As a pivotal technological catalyst and core driver within the electronic value chain, the semiconductor industry's resilience is attributed to the combination effect of continuous technological innovation, diverse application domains, a globalized supply chain framework, strategic partnerships, and governmental support (B.-N. Hwang et al., 2008). These elements collectively enable the semiconductor sector to exhibit strong adaptability and recovery capabilities in global crises.

3.1.3. Technology advancement

Furthermore, initially described by Gordon E. Moore in 1965, the Director of R&D at Fairchild Semiconductor, and presently Chairman Emeritus of Intel Corporation—articulated what has become a reference of semiconductor technology's progress: Moore's Law (Schaller, 1997). Moore observed that the number of transistors on an IC tends to double approximately every two years, with the growth trajectory of microprocessors being exponential, as seen in Figure 3.2 (Max Roser & Mathieu, 2023).

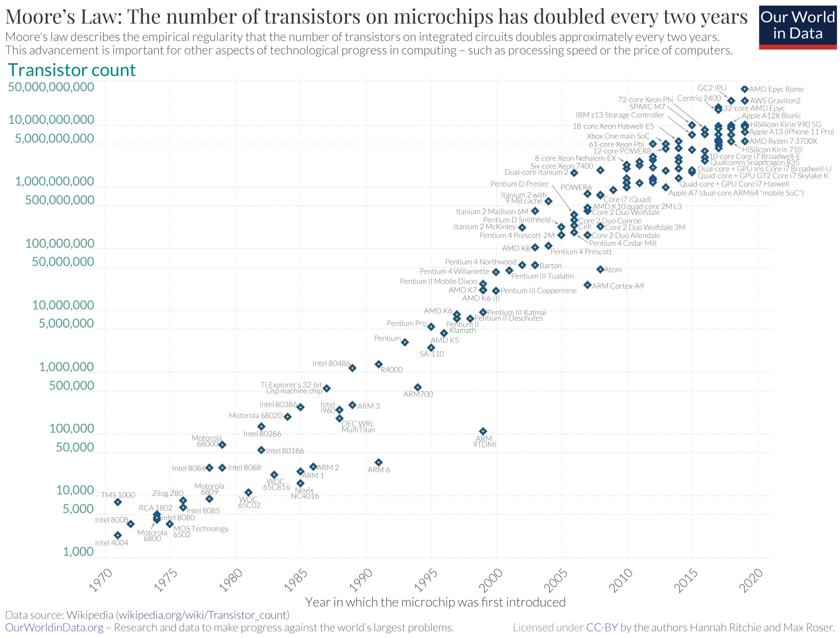

Figure 3.2: The growth in transistor density – the number of transistors on integrated circuits – from 1970 onwards, Max Roser and Mathieu (2023, p. 2)

The prescience of Moore's Law has been such that it has been used as a guiding principle for technological evolution in the semiconductor industry. It has stimulated ongoing innovation, compelling the industry to pioneer novel materials, devices, and fabrication techniques to sustain the scaling trend (Mallik et al., 2015). As a result, the semiconductor industry has been instrumental in driving global economic growth, promoting technological breakthroughs, and instigating societal transformations in the latter half of the twentieth century. This relentless push towards miniaturization has led to influential innovations in the field of semiconductor manufacturing, including the development of advanced lithography techniques and materials. From the metal-oxide-semiconductor field-effect transistor (MOSFET), which has dominated the semiconductor industry for over forty years, to the FinFET technology that has ruled the industry in the past decade with its low power consumption and high-efficiency characteristics, and the ongoing research into gate-all-around (GAA) transistors (Das et al., 2024). Furthermore, the industry is investigating alternative materials beyond traditional silicon, such as silicon carbide (SiC) and gallium nitride (GaN), to enhance performance and efficiency. Today's proliferation of personal computing, the ascendancy of the Internet, and the ubiquity of smartphones are all phenomena that have thrived on the continuity of Moore's Law (Keyes, 2006).

3.2. The emergence of business models

The diversification of business models has accompanied the semiconductor industry's evolution in response to escalating manufacturing costs and the rapid pace of technological innovation. This evolution has led to the derivatives of three primary business models: Integrated Device Manufacturers (IDM), foundries, and fabless companies.

3.2.1. Integrated Device Manufacturer

Before the 1980s, vertical integration at the IDMs was a norm in the semiconductor industry (R. Kumar, 2011). These companies, symbolized by corporations like Intel and Samsung, allow for a high degree of control over the entire value chain: own and operate their silicon-wafer fabrication facilities, develop their process technology for manufacturing chips and carry out the assembly and testing of chips. This model enables quality control, and incorporates innovative technologies by tightly integrating design and manufacturing processes in industries characterized by rapid iteration and customization, e.g. automotive and aerospace (N. Kumar et al., 2006). Shahzad et al. (2011) argue that an IDM is capable of modelling its design and manufacturing interface complexities and serving as a platform for faster and superior knowledge capitalization. Furthermore, owning manufacturing capabilities allows IDMs to protect their intellectual property more effectively, a non-trivial advantage in a highly competitive and technology-driven industry. However, the foremost challenge among these IDM companies is the high capital expenditure required to establish and maintain state-of-the-art fabrication facilities. The cost of building a modern semiconductor fabrication plant (fab) can run into billions of dollars, with the investment risk exacerbated by the rapid pace of technological obsolescence (Brown et al., 2005). Additionally, the complexity of managing the entire production process can lead to inefficiencies and reduce agility in responding to shifting market trends compared to more specialized companies.

3.2.2. Fabless

In the 1980s, an innovative fabless model emerged wherein new ventures in the semiconductor industry started forming without in-house fabrication units (Sarma & Sun, 2017). The fabless model represents a significant shift and the strategic response to the industry challenge described above, epitomized by companies like Qualcomm, emphasizing a design-centric approach where outsourcing manufacturing to foundries. This model allowed for greater flexibility and innovation, as companies could concentrate their resources on R&D exclusively, accelerating the pace of innovation without the capital expenditure associated with building and maintaining fabrication facilities (Shin et al., 2017). By not being tied to their own manufacturing processes, fabless firms can move swiftly to adopt new technological advancements and respond to customer needs more effectively (Collins, 2004). Moreover, the symbiotic relationship between fabless and foundry enterprises has led to the emergence of the Fabless-foundry model, a significant and evolving aspect of the semiconductor industry (Hung et al., 2017). This collaboration is not only about outsourcing manufacturing but also involves deep technological partnerships to ensure that chip designs are optimized for the manufacturing capabilities of foundries (Saha, 2013). Such partnerships are crucial for pushing the boundaries of semiconductor technology, enabling the development of complex system-on-chip (SoC) solutions that cater to the demands of modern electronic devices.

3.2.3. Foundry

Nearly at the same time, the globalization of the semiconductor industry in the late 20th century, with significant manufacturing shifts to Asia, particularly to Japan, South Korea, and Taiwan, marked another critical development phase (Yeung, 2016). The capital-intensive nature of modern semiconductor fabrication led to the emergence of specialized foundries (Brown et al., 2005). Taiwan's establishment of the first pure-play foundry, Taiwan Semiconductor Manufacturing Company (TSMC), in 1987 represented a paradigm shift towards the foundry model, underscoring the industry's increasing specialization and global interdependence (Mathews, 1997). In contrast to fabless, foundries, represented by companies like TSMC and GlobalFoundries, are dedicated exclusively to semiconductor fabrication, focusing on chip processing and manufacturing. The foundry model, a cornerstone of today's semiconductor industry, was pioneered by Taiwan. This model, characterized by manufacturing facilities that produce chips based on customer designs without owning any products, has facilitated the rise of fabless companies and reshaped industry dynamics (Liu, 2021). Foundries' market positioning is significantly influenced by their technological capabilities and the strategic partnerships they foster. The founding of TSMC offered a means of survival to fabless firms through strategic partnerships (Sarma & Sun, 2017). Adopting advanced manufacturing processes, including mature, medium, and advanced process technologies, creates new opportunities for fabless semiconductor companies while offering new outsourcing prospects for IDMs. The business coverage of the three business models can be seen in the below Figure 3.3.

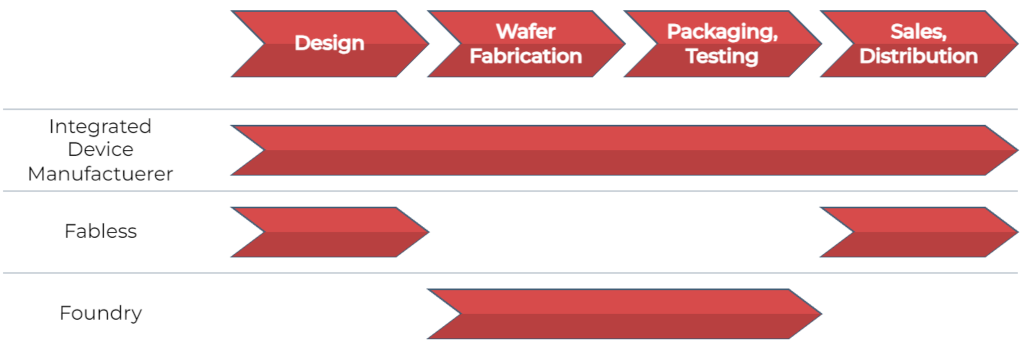

Figure 3.3: Simplified semiconductor ecosystem

3.3. Competitive dynamics of the semiconductor industry

Competitive dynamics within an industry are shaped by a series of actions, i.e., initiatives, and reactions, i.e., countermeasures, undertaken by firms (K. G. Smith et al., 2005). In his 1942 theory of ”creative destruction,” Schumpeter (1942) emphasized that understanding competitive dynamics requires examining the interplay of these actions and reactions and their consequences. The evolution of the semiconductor industry is significantly driven by the interactions among IDMs, fabless companies, and foundries. Schumpeter posited that the innovative actions of challengers gradually erode the leader’s position, eventually replacing them and initiating a new competitive cycle.

3.3.1. The debut and competitive challenges of fabless

Historically, the semiconductor industry’s early development heavily relied on the symbiosis of design and manufacturing processes, making the IDM business model the standard for early semiconductor companies (Y.-T. Li et al., 2011). However, the emergence of fabless and foundry business models has disrupted the traditional IDM dominance.

The landmark release of Intel’s 16-bit microprocessor 8086 in 1978, pioneering the x86 architecture era, and IBM’s introduction of the first PC, IBM 5150, in 1981, marked the beginning of widespread computer application. This period indicated the onset of an era characterized by PC consumer-driven chip technology innovation and industrial development. During this era, the evolution of terminal application forms illustrated a developmental trajectory of ”computational power decentralization” down to the individual level.

Against this backdrop, the period from 1980 to 2010 marked a proliferation era for the establishment of semiconductor product companies, exemplified by the founding of Xilinx in 1984. Subsequently, the establishment of renowned semiconductor firms such as Qualcomm, NVIDIA, and MediaTek followed suit (Yeung et al., 2023). Concurrently, as the number of semiconductor companies burgeoned, so did the construction costs of corresponding wafer fabrication lines, as shown in Figure 3.4. Given the capital-intensive nature of the semiconductor manufacturing sector, the investment required to establish a manufacturing facility, also known as fab, could exceed the costs of setting up a fabless entity by up to tenfold (Hung et al., 2017). Hence, emerging semiconductor product companies found themselves increasingly unable to undertake the substantial capital expenditures associated with constructing, maintaining, and upgrading wafer manufacturing lines since the 1980s.

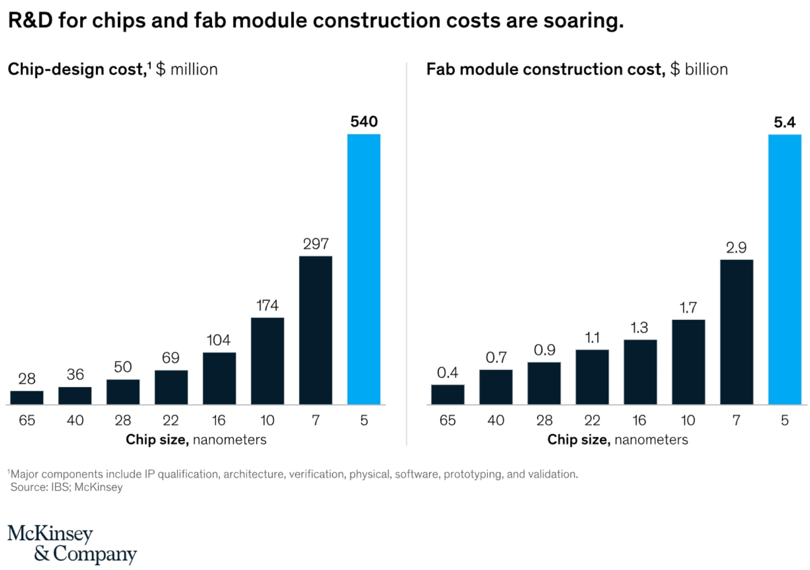

Figure 3.4: R&D expenditures comparison for chips and fab module, Bauer et al. (2020, p. 5)

In this context, the advent of the fabless model emerged as a strategic response to mitigate costs and enhance operational efficiency. Comparatively, even if a nascent semiconductor product company could invest in and establish a wafer manufacturing line (thus becoming an IDM), and notwithstanding its product shipments could sustain adequate capacity utilization rates for the manufacturing line, achieving short-term cost competitiveness remained a formidable challenge (Bauer et al., 2020).

3.3.2. Comparison of IDM and fabless models

Theoretically, the dynamic between IDM and fabless models can be analogized to the distinction between outright capacity acquisition versus capacity leasing. In accord with the arguments by Collins (2004) and Hung et al. (2017), the relationship between their wafer submission costs and frequency of submissions can be understood through the below schematic Figure 3.5, illustrates that initially, IDM's wafer submission costs are higher, rendering their products less cost-competitive than fabless entities.

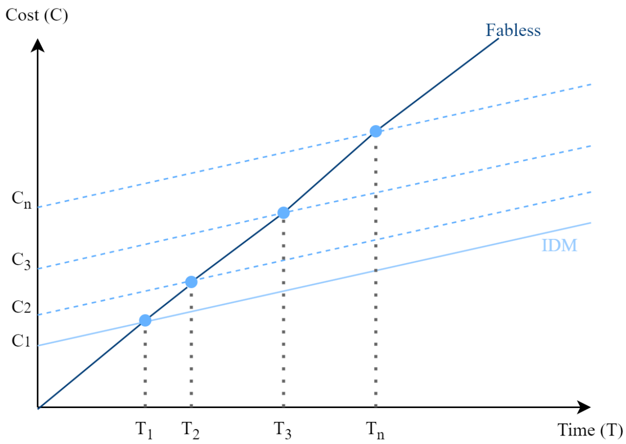

Figure 3.5: Wafer submission costs between IDM and fabless models over time

As the capital costs associated with establishing wafer manufacturing lines incrementally escalate, the timeframe for IDMs to develop a cost advantage over fabless entities correspondingly extends (Collins, 2004). In contrast, by outsourcing the wafer manufacturing phase, fabless companies can significantly reduce startup costs. Together, as semiconductor processing technologies advance, the design costs of chips have also been on an upward trajectory. Fabless firms, therefore, channel their limited resources into the design phases of semiconductor intellectual properties (IPs), architectures, and validations, thereby achieving cost reduction and operational efficiency. Moreover, semiconductor products' initial complexity is limited, enabling companies to complete designs from foundational to top-tier levels independently. However, as IC scales expanded, employing pre-designed and verified modules to construct complex circuit systems gradually became a pivotal strategy in semiconductor circuit design, thus fostering the inception of semiconductor IP cores (Gutmann, 1999). The development and reuse of IPs streamlined the design process, reduced redundant design costs, shortened development cycles, and enhanced the success rate of product development. To some extent, this approach lowered the technical barriers to semiconductor product design, creating a more conducive industrial ecosystem for the emergence of fabless entities. Additionally, the portability of IPs across different semiconductor manufacturing processes intensified the decoupling of semiconductor design and manufacturing phases, laying the groundwork for the emergence of foundries (S. Lee, 2014).

3.3.3. The inevitable emergence of the foundry model

Since the transistor's invention in 1947, it has experienced continuous enhancements and refinements across various dimensions, including working principles, materials, structures, functions, and integration/discrete forms (Brinkman et al., 1997). Innovations at the transistor integration level have predominantly influenced logic circuit upgrades, establishing a foundation for semiconductor process standardization (H. Chen et al., 2020). 1987, the global debut of the first foundry—TSMC—appeared. Within the domain of semiconductor products typified by logic chips, as production scales expanded, the scale effects of the wafer manufacturing outsourcing model began to manifest. For IDMs and foundries operating under a pure wafer outsourcing model, assuming that other variables (e.g., the cost of equipment, materials, and the selling price of produced wafers) remain constant, their benefits correlate directly with their respective production scales (Ziarnetzky & Mönch, 2016). Based on M. Chang (2007)'s comparative discussion of IDM and foundry economies of scale, the changes in production scale between the two over time are shown in the following schematic Figure 3.6. Before reaching equilibrium point E, if the total market's outsourced production scale is lesser than IDM's production scale, constructing an equivalent wafer manufacturing line would yield a superior scale effect for IDM, thereby granting its products with a cost advantage.

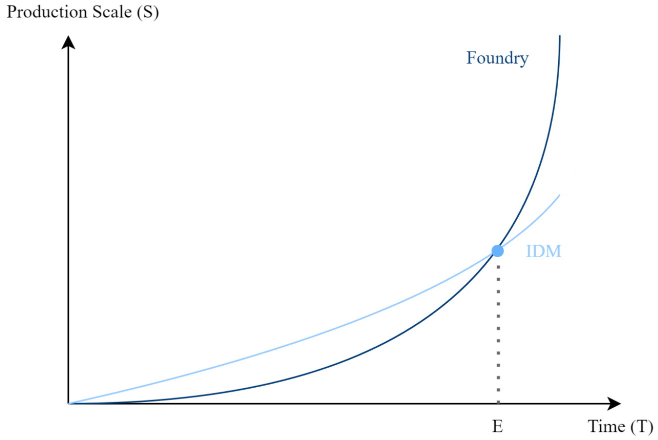

Figure 3.6: Production scales between IDM and foundry over time

Beyond point E, due to an increase in semiconductor product shipments coupled with the advent of fabless companies, several IDMs alone are insufficient to meet the entire market's production needs, whereas foundries can flexibly cater to the entire market's production orders. Consequently, foundries have a stronger scale effect and possess greater market competitiveness when constructing equivalent wafer fab positions compared with IDMs because their average production cost is lower (Oh, 2010).

As for TSMC, the foundry model giant, it dominates with over half the market share and a profit margin exceeding 50% (Wang & Lin, 2021). Its success is attributed to its open model strategy, ensuring production volume while maintaining levels of differentiation, enabling it to capture market trends and significant opportunities. TSMC's success is fundamentally due to its keen insights into competitive dynamics in the industry and strategic self-regulation. Therefore, this study includes conducting a detailed case study on TSMC within the foundry model.

3.3.4. Navigating competitive challenges in the rapidly advancing industry

As predicted by Moore's Law, the semiconductor industry, characterized by high capital intensity and short product life cycles, experiences rapid and continuous technological progress across devices, architecture, and processes, as illustrated in Figure 3.7.

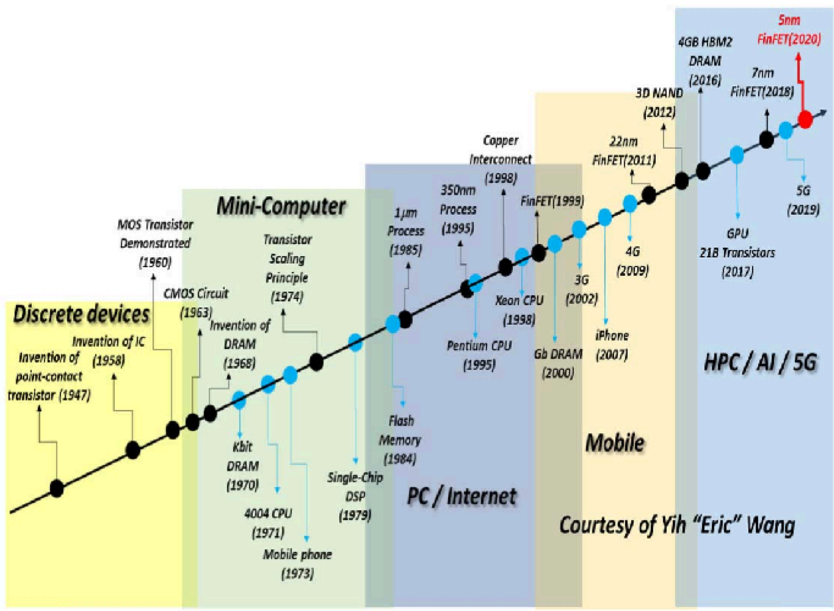

Figure 3.7: Semiconductor technology application evolution, T.-Y. J. Chang et al. (2020, p. 187)

Companies must continually and creatively undertake actions that enhance or improve profits, competitive advantage, and industry position, prompting competitors to respond by either thwarting or imitating these actions (K. G. Smith et al., 2005). The industry requires significant capital investment in R&D, manufacturing facilities, and technology upgrades, with competitive dynamics influencing investment decisions and resource allocation. Additionally, the semiconductor industry contains multiple market segments and tracks, such as consumer electronics, automotive, industrial, and telecommunications, with competitive dynamics affecting how companies position themselves within these segments. Furthermore, the industry is subject to various regulatory frameworks and trade policies; thus, competitive dynamics play a crucial role in how companies respond to these regulations, including issues related to intellectual property rights, trade restrictions, and environmental standards.

3.4. Strategic adaptations of the semiconductor companies

Adaptation refers to the actions taken by an entrepreneur and their team to process information from the external environment and make rapid adjustments based on this feedback (McKee et al., 1989; Stoica & Schindehutte, 1999; Woo et al., 1991). In this context, the environment encompasses the industry's competitive dynamics and strategic positions. Strategic adaptations are characterized by changes, adjustments, and modifications in strategic behaviour to align more effectively with this environment. Given that no organization remains entirely static over time, some degree of adjustment, change, or improvement is intrinsic to the operation of any venture (Schindehutte & Morris, 2001).

Competitive strategy is a critical determinant in achieving higher operating profits and enhancing business performance at the internal enterprises, and strategic management enables organizations to sustain a competitive advantage over the long term (C. Lin et al., 2020; Slater et al., 2010). For industries like semiconductors, which are intensely driven by capital and technology, the strategic nature of chip semiconductor competition among nations and corporations has amplified under the influence of digital economics and geopolitical factors. In such a complicated and uncertain business environment, strategic formulation and adjustment become particularly crucial for semiconductor firms. Specifically, enterprises must identify their goals during the strategy formulation process, analyse internal and external environments, develop various strategic options, and further develop competitive advantages (Delery & Roumpi, 2017).

3.4.1. Strategic evolution of the rise of the Fabless-foundry model

Prior to the 1980s, the semiconductor industry was predominantly IDM-oriented, with business models encompassing both IC design and manufacturing (Hung et al., 2017). Major players like Intel, Texas Instruments, Samsung, and Micron, which managed the main processes of chip design, production, and packaging testing themselves, are included. These IDM companies would occasionally offer a small amount of manufacturing services to other enterprises when production line utilization was low, but there were hardly any companies in the market focusing primarily on manufacturing services. In the 1980s, an innovative fabless model emerged, where new semiconductor enterprises started forming without internal manufacturing units (Sarma & Sun, 2017). However, as mentioned above, the unpredictability of IDM production outsourcing not always being available for fabless use, especially during peak periods, because they could only offer excess capacity to fabless companies (Hung et al., 2017). Soon after, the establishment of TSMC in 1987, the first company with a foundry business model as its main business, addressed this significant demand for outsourced production. The fabless model, represented by companies like Qualcomm, was a strategic response to industry challenges, focusing on chip design while outsourcing manufacturing to foundries.

As non-competitive business partners, fabless and foundry companies formed strategic alliances, known as the Fabless-foundry model (Hung et al., 2017). This collaborative strategic model allowed fabless enterprises to respond quickly and flexibly to industry changes, concentrating resources on design and product development without engaging in the risks associated with high fixed manufacturing costs (Gao et al., 2023). By pooling demands from various fabless companies, foundries reduced the risk of demand declines due to individual fabless company sales failures, thereby achieving a cooperative advantage in risk-sharing (Chatterjee et al., 1999; Ku et al., 2007). Additionally, the Fabless-foundry model, through adopting modular design and manufacturing, shortened the cycle from IC design to mass production, and foundries shared development costs by pre-validating process reliability, thereby enhancing overall operational efficiency (Cheng et al., 2012; Saito, 2009; Wu et al., 2006).

3.4.2. The decline of IDM's competitive edge

The IDM model has been losing competitive advantage compared to the combined fabless and foundry models (Hung et al., 2017; Wang & Lin, 2021), mainly due to the rapid globalization of the semiconductor industry and the huge advantages in specialization and efficiency brought about by the integration of fabless and foundry business models (Qiao & Wang, 2021), as shown in Figure 3.8.

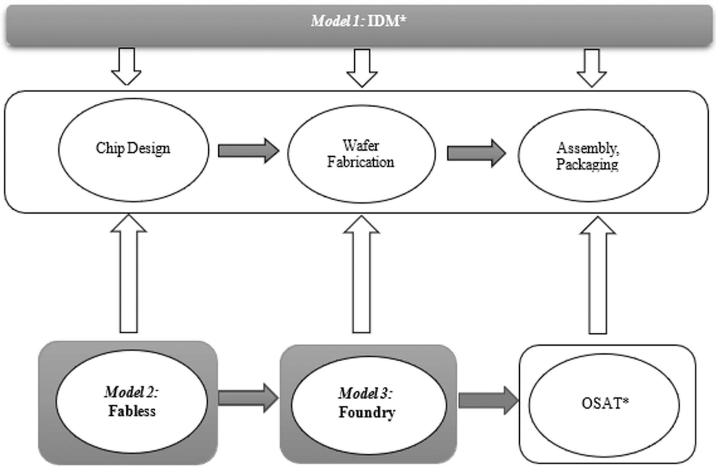

Figure 3.8: Three business models in the semiconductor value chain. *IDM: Integrated Device Manufacturer. *OSAT: outsourced semiconductor assembly and test. Modified from Kleinhans and Baisakova (2020, p. 6)

In 2014, IDM giant Intel launched its first CPU using the 14nm process, claiming its technology was not inferior to Samsung and TSMC's 10nm process, and continued to rely on this process in 2017. However, Intel faced significant setbacks as its 10nm and 7nm process developments were repeatedly delayed, allowing competitors like AMD to gain market share using TSMC's advanced manufacturing processes. To address these challenges and the growing public awareness of its technological lag, Intel announced a new business strategy, IDM 2.0, in March 2021, which involved investing $20 billion in new manufacturing facilities in Arizona to develop 7nm processors for computers and opening its foundry services to other fabless manufacturers, marking a significant strategic pivot for the company. Research by Anzenbacher and Wagner (2020) hypothesized how different business models in the semiconductor industry could balance the ambidexterity of exploration and exploitation in innovation output (March, 1991; Wernerfelt, 1984). The results indicated that, compared to IDMs, foundries benefited more from exploration activities, while fabless companies gained the most substantial benefits from ambidextrous strategies, with efficiency reaching a notable peak (Anzenbacher & Wagner, 2020). Thus, semiconductor firms need to carefully compare the relative relevance of their internal knowledge acquisition mechanisms to mechanisms that promote external knowledge spillovers to decide on appropriate strategic actions, such as forming strategic alliances or making strategic acquisitions (Anzenbacher & Wagner, 2020). Additionally, work by Yung-Cheng et al. (2007) highlighted the primary challenge for most IC design companies (i.e., fabless companies) in the IC design cycle as cost and cycle time (Jou, 2004), proposing a novel and effective Engineer-Chain business model and Engineer-Chain Management System (ECMS) that ensures successful and efficient IC design cycles by addressing challenges in distributed work environments and advanced process design.

However, Intel is still chosen for the IDM case study due to its representative status and significant influence within this business model, with peers often emulating its strategies. Moreover, Intel's longstanding rivalry with AMD, another company that originated as an IDM, adds to the relevance. Faced with differing circumstances, these companies have made distinct strategic choices in response to shifts in the semiconductor industry model, such as AMD's gradual transition from an IDM to a fabless company with the rise of the fabless model. This transition underscores the research significance of Intel's case within the IDM model.

In addition, AMD, like Intel, initially started as an IDM but lacked sufficient market position and R&D advantages against Intel, which had already established a leading edge during that era. AMD was even on the verge of bankruptcy. However, a pivotal decision in 2009 to transform the company marked a turning point in AMD's fate. It decided to transition into a fabless model, divesting its final ownership shares of the spun-off foundry in 2012 (Sarma & Sun, 2017). AMD abandoned the IDM model, choosing a light-asset operation by leveraging TSMC's advanced process technologies for wafer manufacturing, focusing on R&D and the design of chips. In October 2020, AMD released its latest Zen3 architecture processors with a 26% performance improvement, outperforming Intel and becoming the strongest gaming processor at the time (Horro et al., 2022). From being a loser in the previous era, AMD's strategic transformation in response to competitive dynamics has led to its current success, making the AMD case highly meaningful for research.

3.5. Theoretical linkages between strategic adaptations and competitive dynamics in the semiconductor industry

This study aims to develop propositions by examining the relationship between competitive dynamics, strategic adaptations, and market performance. Competitive dynamics and strategic adaptations are inherently broad and abstract concepts. Consequently, the objective of this research aligns with the goals of exploratory studies, which are hypothesis generation and conclusion establishment. To this end, the study employs a case study methodology, selecting three companies that exemplify different business models as the subjects of analysis. Within these case studies, competitive dynamics and strategic adjustments are concretely manifested through objective case data, thereby facilitating the formulation and validation of propositions. As noted by Eisenhardt (1989), case studies are instrumental in generating new insights and understanding phenomena. They are particularly effective in exploring complex issues characterized by multiple variables and interactions (Yin, 2009).

3.5.1. Anderson and Tushman's Cyclical Model of Technological Change

The relationship between competitive dynamics and strategic adaptation is not a straightforward cause-and-effect interaction; rather, it is a complex, interwoven concept characterized by a feedback loop where each influences the other within the semiconductor industry. Competitive dynamics drive strategic adaptation, which in turn reshapes the competitive landscape. This relationship can be understood through the cyclical model of technological change proposed by Anderson and Tushman (1990), as depicted in Figure 3.9.

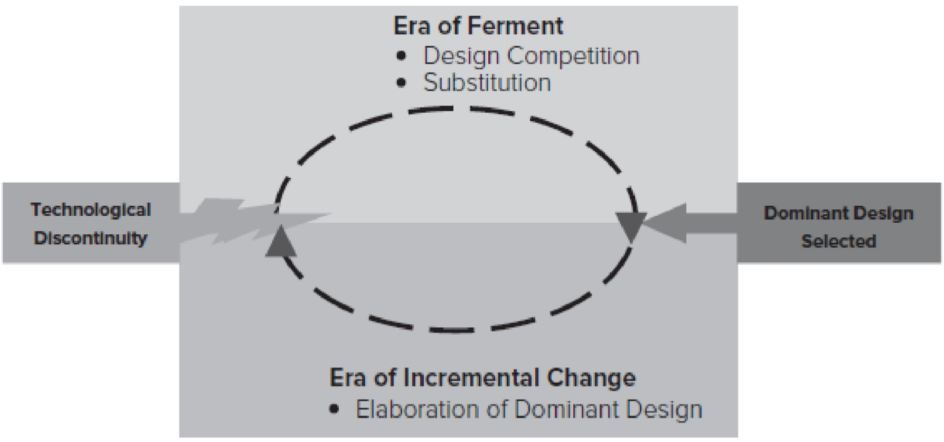

Figure 3.9: The cyclical model of technological change, Schilling (2017, p. 61)

The semiconductor industry has undergone multiple cycles of technological discontinuities and evolutions, such as the transition from vacuum tubes to transistors, from bipolar junction transistors to MOSFETs, and ongoing innovations in areas like quantum computing and nanotechnology. These technological discontinuities disrupt competitive dynamics, compelling companies to adjust their strategies to emphasize design competition and substitution. However, the emergence of dominant designs tends to stabilize the competitive environment, enabling companies to concentrate on strategic development through incremental improvements and efficiency enhancements. The high volatility of the semiconductor industry is manifested in these cyclical changes. Competitive dynamics can range from turbulent to stable, while strategic adaptation can vary from active and disruptive to passive and incremental. To sustain competitive advantage and ensure long-term success, companies must engage in continuous strategic adjustments to effectively navigate the dynamic interplay between competitive dynamics and strategic adaptation.

3.5.2. Barney's Resource-Based View

Resource-Based View (RBV) posited by Barney (1991) claimed that a firm's sustained competitive advantage is derived from its capacity to acquire and manage resources that are valuable, rare, inimitable, and non-substitutable (VRIN). These resources include tangible assets, intangible assets, and organizational capabilities. According to Barney, competitive advantage is defined as when a firm is able to implement a value-creating strategy that is not simultaneously being implemented by any current or potential competitors. Within the semiconductor industry, competitive dynamics are profoundly shaped by the unique resources held by companies. Tangible assets, such as human capital with advanced technical skills and expertise, and state-of-the-art semiconductor technologies—new materials, innovative design architectures, and advanced process nodes and intangible assets, including semiconductor intellectual property, brand equity, customer relationships, and supplier networks, are all constitute valuable and rare resources that are challenging for competitors to replicate or substitute. Firms engage in strategic adaptations by leveraging these resources to shape the competitive dynamics or, conversely, by modifying their strategies in response to these dynamics, which refers, as mentioned earlier, to proactive strategic actions or reactive strategic reactions.

3.5.3. Teece, Pisano, and Shuen's Dynamic Capabilities Framework

As previously mentioned, any organization will undergo some degree of adjustment, change, or improvement in its operations, as no organization remains entirely static over time (Schindehutte & Morris, 2001). Teece et al. (1997), building on the RBV, proposed the dynamic capabilities framework, emphasizing a firm's ability to integrate, establish, and reconstruct internal and external resources to address rapidly changing environments. Dynamic capabilities are crucial for firms in the rapidly iterating and highly competitive semiconductor industry, particularly regarding organizational agility, which includes sensing and shaping opportunities and threats, seizing opportunities, and maintaining competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the firm's tangible and intangible assets (Winter, 2003).

The competitive dynamics in the semiconductor industry are essentially shaped by the dynamic interactions of numerous firms. For instance, as the fabless model gained traction and became a noticeable trend, traditional IDM companies sensed this shift and seized the opportunity presented by the concurrently emerging foundry model to engage in manufacturing outsourcing collaboration. This strategic move, involving reconfiguring tangible and intangible assets originally structured under the IDM model, is a pertinent reflection of the dynamic capabilities framework. By sensing the current competitive dynamics, firms strategically adapt to seize opportunities, thereby reshaping industry competition dynamics and vice versa.

3.6. Market performance evaluation indicators

When evaluating the market performance of the three business models of IDM, fabless and foundry in the semiconductor industry as a result of competitive dynamics and strategic adaptations, commonly used performance indicators that reflect the current health and success of the business entity are used and judged comprehensively. The research conducted by Hung et al. (2017) leverages fifteen years of revenue and market share data across the three business models to examine the risk-sharing and operational efficiency benefits brought about by the Fabless-foundry collaboration model, as illustrated in Figure 3.10 and Figure 3.11.

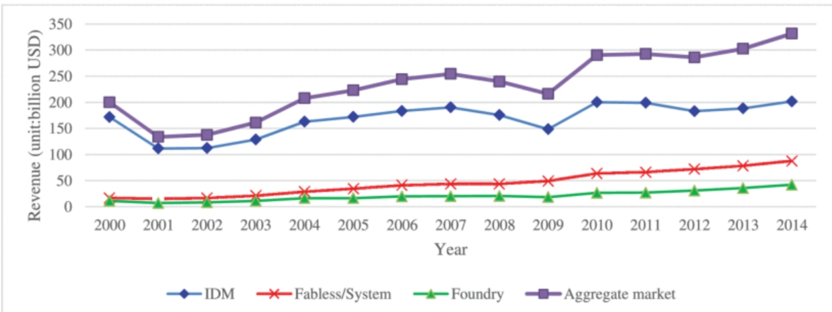

Figure 3.10: Revenue of the three major semiconductor industry business models, Hung et al. (2017, p. 255). Data sources: IC Insights (2015). Data collation: Market Intelligence & Consulting Institute of Taiwan.

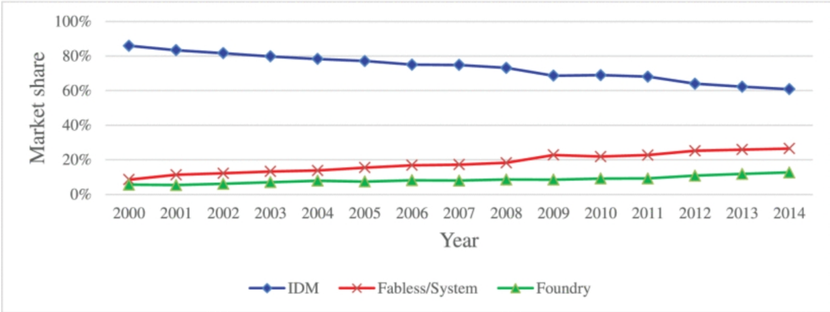

Figure 3.11: Market share of the three major semiconductor industry business models, Hung et al. (2017, p. 255). Data sources: IC Insights (2015). Data collation: Market Intelligence & Consulting Institute of Taiwan.

Furthermore, the study by Anzenbacher and Wagner (2020) employs marginal effect curves to demonstrate how the balance of exploration and exploitation within semiconductor industry business models can modulate the impact on innovation performance based on the pursued corporate strategies. The 2022 McKinsey & Company Semiconductor Practice report utilizes the Herfindahl-Hirschman Index (HHI) to indirectly indicate market performance, as depicted in Figure 3.12.

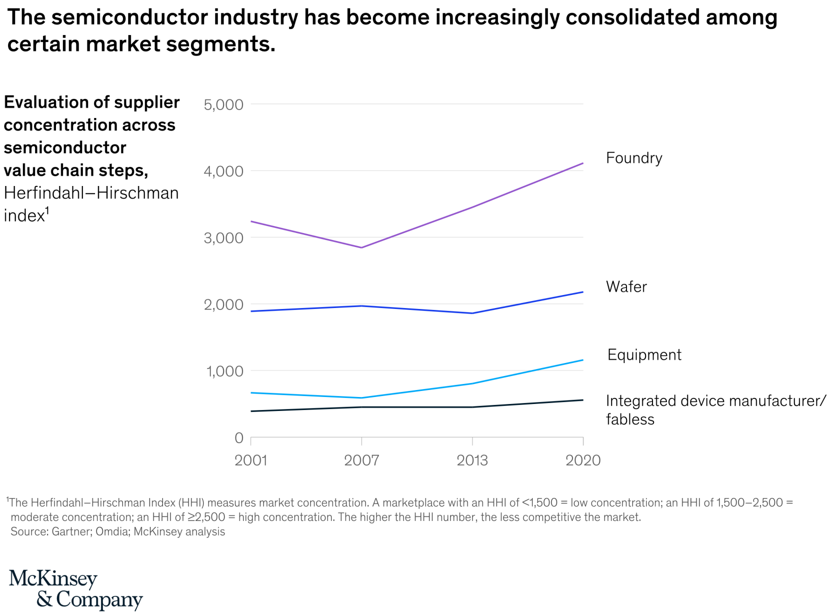

Figure 3.12: Evaluation of supplier concentration across semiconductor value chain steps, Herfindahl-Hirschman Index, Burkacky, de Jong, and Dragon (2022, p. 4)

The findings reveal a notable variation in the HHI for foundries over the years, suggesting higher market concentration and a less competitive environment with a few foundries dominating the market. Conversely, the HHI in the IDM and fabless sectors has consistently remained below 1,000, denoting a competitive market with numerous active competitors and lower market concentration.

Other indicators such as profit margins, which directly represent a company's operational efficiency and pricing power, and innovation rate, a key performance indicator in a technology-driven industry, manifesting in the number of patent filings and R&D expenditures, are considered in this study.

Given that technological innovation, scale, and efficiency are critical indicators of success within the semiconductor industry, and considering the intricate interplay of competitive dynamics and strategic adaptations on market performance for semiconductor business models, this study has to consider multiple aspects of market performance indicators.

3.7. Summary of findings

From its inception with the invention of the point-contact transistor in 1947, the semiconductor industry has undergone significant evolution marked by key technological advancements such as the IC and the microprocessor. These milestones triggered substantial growth, with the industry's annual sales revenue surpassing $481 billion by 2018 (G. Chen, 2019). This growth underscores the industry's decisive role in modern electronics, serving diverse application areas like consumer electronics, automotive, industrial automation, and artificial intelligence. Despite the challenges posed by the COVID-19 pandemic, which disrupted global supply chains, the semiconductor industry demonstrated remarkable resilience. This resilience is attributed to continuous innovation, strategic partnerships, and a globalized supply chain framework, enabling the sector to adapt and recover swiftly.

Initially dominated by IDMs, which manage the entire production process, the industry has seen a shift with the rise of fabless companies and foundries. Competitive dynamics in the semiconductor industry are driven by a series of strategic actions and reactions among firms (K. G. Smith et al., 2005). The rise of fabless companies posed significant challenges to the traditional IDM model, prompting strategic adaptations such as outsourcing manufacturing processes. The Fabless-foundry model emerged as a strategic response to these challenges, enabling firms to concentrate on innovation and design while leveraging the manufacturing capabilities of foundries. This model promoted a more efficient allocation of resources and a faster response to market changes. The continuous advancement in semiconductor processing technologies and the development of semiconductor IP cores further streamlined the design process, reducing costs and enhancing product development success.

The Cyclical Model of Technological Change, the Resource-based View, and the Dynamic Capabilities Framework are used to illustrate the theoretical linkages between competitive dynamics and strategic adaptations in the semiconductor industry, emphasizing the feedback loop between these two concepts. Evaluating the market performance of semiconductor business models involves assessing various indicators such as revenue, market share, profit margins, and innovation rates. Studies indicate that the Fabless-foundry collaboration model offers significant benefits regarding risk-sharing and operational efficiency, reflected in long-term revenue and market share data Hung et al. (2017). Overall, technological innovation, scale, and efficiency remain critical success indicators, shaped by the dynamic interplay of competitive dynamics and strategic adaptations within the semiconductor industry.

4

Comparative analysis

This chapter presents a comparative analysis of the IDM, fabless, and foundry business models within the semiconductor industry. The analysis is structured around the Business Model Canvas (BMC) framework, examining 4 orientations with 9 key elements: supply and resources-oriented (key partners, key activities, key resources), value-oriented (value proposition), demand-oriented (customer relationships, channels, customer segments), and financial-oriented (cost structure, and revenue streams). The C-STOF model analysis is also included for the internal inspections regarding the customer value, service, technology, organization and finance of the three selected case companies: Intel, AMD and TSMC. This chapter aims to uncover the core differences between the business models by exploring these elements.

4.1. Business Model Canvas analysis of IDM, fabless and foundry

To facilitate a clear and organized analysis, this chapter begins by presenting an integrated Business Model Canvas table that holistically summarizes the key elements of IDMs, fabless, and foundries. Subsequent sections of the chapter are structured around each BMC element. Propositions are developed at the end of each subsection to synthesize the findings from each subsection. These propositions encapsulate the key differences identified during the analysis. Finally, the chapter concludes with a summary of these propositions, providing a cohesive understanding of each business model's specialities and features and their essential differences to answer SQ1, as illustrated in the subsection 1.3.2.

4.1.1. Integrated Business Model Canvas table

Table 4.1: Business Model Canvas of IDM, fabless and foundry

Criteria	IDM (Integrated Device Manufacturers)	Fabless	Foundry
Key partners	Software providers, equipment manufacturers, raw material suppliers	Foundries, software providers, OSATs, IP vendors	Fabless, equipment manufacturers, raw material suppliers
Key activities	Chip design, wafer fabrication, packaging & testing, Sales & distribution	Chip design, sales & distribution	Wafer fabrication, packaging & testing

Continued on next page

Table 4.1: Business Model Canvas of IDM, fabless and foundry (continued)

Criteria	IDM (Integrated Device Manufacturers)	Fabless	Foundry
Key resources	Manufacturing facilities, human capital, intellectual property, supply chain infrastructure	Intellectual property, design and simulation software, human capital, Partnership networks	Advanced manufacturing facilities, human capital, technological expertise, partnership networks
Value proposition	Products sold: Semiconductor products Customer needs: Solutions Reasons for buying: Integrated service, reliability, continuity	Products sold: Chip design, IP Customer needs: Innovation, specialization Reasons for buying: Cutting-edge performance and functionality, efficiency	Services sold: Semiconductor manufacturing services Customer needs: Capital efficiency, operational enabling Reasons for buying: Scalability, efficiency, technological expertise
Customer relationships	Loyal customers, close, direct, customized	Innovation-driven, sustainable, profitable, customized	Process level customized, long-term partnerships (with fabless)
Channels	B2B, direct sale, adaptive go-to-market strategies, authorized distributors	B2B, website, media	B2B, open process service platform, direct sale, business contacts, website
Customer segments	OEMs, telecommunications companies, automotive Companies, fabless	OEMs, automotive companies, telecommunications companies, cloud service providers, IDM	Fabless, IDMs
Cost structure	R&D (chips), manufacturing (CapEx, OpEx), supply chain, marketing and sales, IP licensing	R&D (chips), manufacturing (foundry), IP licensing, marketing and sales	R&D (process), manufacturing (CapEx, OpEx), quality control and test
Revenue Streams	Electronics, mobile communications, solutions, IoT, automotive	Chips, IP cores	Manufacturing services

4.1.2. Supply and resources-oriented

Key partners

According to Haaker et al. (2018), identifying key partners in a business model involves assessing three critical aspects: the identification of partners and suppliers, the resources acquired from these partners, and the activities undertaken in collaboration with these partners.

IDM
In the context of IDMs, their vertical integration model covers the entire semiconductor production process from design to manufacturing and packaging and even extends to testing and sales. Consequently, IDMs collaborate with dominant software companies in the Electronic Design Automation (EDA) market, such as Cadence, Synopsys, and Mentor Graphics (a Siemens subsidiary), at the chip design level (Thadani & Allen, 2023).

Given the complexity and stringent quality demands of semiconductor manufacturing, the manufacturing aspect requires essential inputs such as silicon wafers, photomasks, photoresists, and certain chemicals, the IDM business model requires consistent and reliable delivery of these materials (Thadani & Allen, 2023). Intel's IDM 2.0 strategy highlights the incorporation of extreme ultraviolet lithography (EUV) in its streamlined process flow, advancing the development of its 7nm technology node (Singer, 2021). EUV lithography is becoming an industry standard exposure metric for key layers at advanced technology nodes above 7nm, whereas the Dutch company ASML serves as the sole supplier of the latest generation lithography scanners (EUV lithography machines) (Fu et al., 2019; Thadani & Allen, 2023).

Overall, the IDM model not only maintains collaborations with chip design software providers but also heavily relies on suppliers of raw semiconductor materials and advanced manufacturing equipment from companies like ASML and Applied Materials. These partnerships are typically long-term and involve significant collaboration on technology development and optimization to meet specific manufacturing needs.

Fabless
Given the capital-intensive nature of the semiconductor manufacturing sector, the investment required to establish a manufacturing facility, also known as fab, could exceed the costs of setting up a fabless entity by up to tenfold (Hung et al., 2017). Therefore, fabless companies, which are primarily engaged in the innovation and design of microchips, are dependent on collaborations with foundries for their manufacturing needs.

In mid-February 1994, the launch of a new industry association called the Fabless Semiconductor Alliance (FSA), which facilitates various partnerships or linkages between modular companies and provides dedicated events - Manufacturing, Register-transfer level (RTL) design, synthesis, verification and validation, package design, board design, test, and assembly and software stacking (Sarma & Sun, 2017; Shih et al., 2008). Fabless companies typically engage in Outsourced Semiconductor Assembly and Testing (OSAT) services to handle the assembly and testing of semiconductor devices once the manufacturing process is concluded.

Fabless chip manufacturers generally pursue one of two main strategies for designing components of a System on a Chip (SoC): they either license technology from an IP vendor or develop designs internally (Linden & Somaya, 2003). The reuse and integration of various IPs—such as processors, interfaces, and codecs for audio or video—are identified as foundational to the value proposition in the SoC era (Y.-T. Lin & Yu, 2010). By forming partnerships with IP vendors, fabless companies are able to incorporate sophisticated features into their products without the need to develop these technologies in-house.

Foundry
The emergence of Taiwan Semiconductor Manufacturing Company (TSMC) as the first dedicated foundry has provided fabless companies with a vital pathway for participation in the market through strategic alliances (Sarma & Sun, 2017). These partnerships have substantially reduced the barriers to entry for IC designers into the semiconductor market, thereby supporting the rapid ascent of fabless companies. In this context, the relationship between fabless firms and foundries often called the Fabless-foundry model, is characterized by a non-competitive collaboration where each entity focuses on its core competencies to foster mutual growth and innovation (Hung et al., 2017). This model exemplifies a strategic alliance where both parties benefit from their specialized capabilities in design and manufacturing, respectively.

Proposition 1.1: IDMs and foundries rely heavily on long-term partnerships with suppliers of advanced manufacturing equipment and raw materials, whereas fabless companies primarily depend on collaborative relationships with foundries and IP vendors.

Proposition 1.2: The relationships between fabless companies and foundries are characterized by a non-competitive, complementary, and mutually beneficial collaboration, while the relationship between fabless companies and IDM is competitive regarding market share and technological advancement.

Key activities

The semiconductor ecosystem can be concisely divided into four primary stages: design, wafer fabrication, packaging and testing, and sales and distribution. The design stage involves developing the architecture and design of semiconductor chips. The wafer fabrication stage consists of producing semiconductor wafers utilizing advanced fabrication technologies. The packaging and testing stage encompasses the encapsulation of semiconductor devices and the execution of rigorous testing to ensure their functionality and reliability. The sales and distribution stage entails the marketing and disseminating the finished semiconductor products to various market segments. Figure 3.3 presented in the section 3.2.3 depicts the key activities associated with each business model, emphasizing their respective focuses and operational scopes.

IDMs are engaged in the entire semiconductor production process, from initial design to final sales and distribution. This vertical integration enables IDMs to maintain stringent quality control and optimize operational efficiency across multiple stages.

Fabless companies concentrate exclusively on the design and development of semiconductor chips, outsourcing the manufacturing process to specialized foundries. These companies often market and distribute their designed chips through partnerships and strategic alliances with distributors and other stakeholders.

Foundries specialize in the manufacturing aspect of semiconductor production, providing fabrication services to fabless companies and occasionally to IDMs. By focusing on wafer fabrication, foundries can achieve economies of scale and invest in cutting-edge technologies to sustain their competitive advantage.

Proposition 2.1: The breadth of business covered by the cooperative model between fabless companies and foundries basically matches the business scope traditionally covered by IDMs without the need for vertical integration.

Key resources

IDM

As mentioned above, IDM's business includes the wafer manufacturing process. IDM invests heavily in its state-of-the-art manufacturing facilities, including the precision equipment required for complex chip manufacturing processes. Intel mentioned in its IDM2.0 strategy that Intel's global internal factory network for large-scale manufacturing is a key competitive advantage that enables product optimization, improved economics and supply flexibility (J. Li, 2023). In addition, Intel intends to build its foundry services and become a major supplier of foundry capacity in the United States and Europe to meet the huge global demand for semiconductor manufacturing. Intellectual property (IP) related to semiconductor design and manufacturing processes constitutes a significant asset for IDMs. Chiang (2001)'s work indicates that this is particularly relevant as the semiconductor industry undergoes further disintegration and the trend towards SoC accelerates the decentralization of the industry. One of the key drivers maintaining this evolution is the increased complexity of designs associated with SoC trends, which compels both foundries and IDMs to concentrate on their core competencies: advanced design and IP management.

A joint study from the Wharton School and ATREG by Kapoor (2012) highlighted the large proportion of reliance of IDMs on internal IP resources, accounting for 84%, which indicates a highly skilled workforce to manage the complex interplay between product design and manufacturing processes. Additionally, the commentary by Varas et al. (2021) from Boston Consulting Group discusses how the semiconductor industry's need for deep technical know-how has resulted in a highly specialized industry structure. This specialization underscores those R&D-intensive activities, such as core IP, chip design, and advanced manufacturing equipment, owing to world-class universities, a vast pool of engineering talent, and a market-driven innovation ecosystem.

The highly specialized industrial structure also implies a highly specialized global supply chain. The global supply chain for IDMs is highly complex and geographically diverse, reflecting the specialized roles that different regions play in semiconductor production. Due to the complexity of IDM's network, strategic alliances among partners and supply chain integration are effective ways to enhance competitiveness and increase profitability (M.-C. Chen et al., 2017).

Fabless

Segments of chip design utilize reusable IP cores, which may either be licensed to external entities or retained and exclusively used by the owning firm. The study on the function of patents as quality signals within the semiconductor industry by Hsu (2007) illustrates that possessing a substantial patent portfolio enhances the probability of a new startup securing initial funding from prominent venture capitalists. This relationship is particularly pronounced in semiconductor fabless companies, where patents serve as a more accurate indicator of innovative activity due to the companies' high degree of specialization (Balconi & Fontana, 2011). Core IP is an indispensable resource for fabless companies whose primary business focus is chip design. The market for core IP was to reach US$5 billion by 2021 (Thadani & Allen, 2023).

Engineers, facing increasingly tough integrated circuit design requirements, need to meet specific characteristics quickly (Novichkova et al., 2021). EDA facilitates optimal design solutions because it reduces the cycles of costly physical prototyping and testing. Since semiconductors' design and manufacturing steps occur in specialized, expensive facilities, the key implementation step for fabless companies is the design phase. To ensure success on the first attempt, both phases heavily rely on using EDA tools (Božanić & Sinha, 2018). Essentially, EDA tools support the core activities of design and innovation in fabless semiconductor companies and significantly enhance their operational efficiency and competitive ability in a demanding market.

Solid relationships with foundries and OSATs ensure that fabless companies can produce their designs efficiently and on a large scale. These partnerships enable fabless companies to leverage the specialized capabilities of their partners, thereby enhancing their focus on design and innovation while effectively managing production risks and costs. Since the mid-1980s, the Fabless-foundry model has facilitated the entry of new fabless firms into the exponentially growing semiconductor industry, and the advantages of risk-sharing and operational efficiency have led to the rapid expansion of this model (Balconi & Fontana, 2011; Hung et al., 2017). Moreover, the importance of design for manufacturability means that fabless companies must work closely with foundries to achieve the desired chip performance and cost efficiencies (Brown et al., 2005).

Foundry
Due to the increasing complexity of nanoscale IC devices and technologies, the role of semiconductor foundries is becoming increasingly crucial for the successful production of SoCs (Saha, 2012). These foundries are required to provide processes that offer high performance, low noise, and low leakage variability. A prime example is TSMC, which, in 2003, derived a significant portion of its revenue from its IC process technology. Its most advanced manufacturing processes, those measuring 0.18 micrometres and below, accounted for approximately 62% of the company's revenue in 2003, even though the mainstream market technologies were still at 0.25 to 0.18 micrometres (C.-W. Lee et al., 2010). The foundry model has created substantial opportunities for fabless companies, fundamentally because it continually invests in developing the most advanced manufacturing technologies as a core resource to produce smaller, more efficient chips.

Another key resource for foundries is establishing solid and enduring relationships with fabless companies. IC design service companies benefit from collaborating with foundries on backend processes, while foundries gain sales leverage from these design service companies to maintain their factory utilization rates, thereby forming close cooperative relationships (Siripitakchai et al., 2015). For example, as the leading foundry, TSMC collaborates closely with companies such as Apple, AMD, and Nvidia. Its clients are relatively concentrated, characterized by high profitability and high diversity (Wang & Lin, 2021).

Proposition 3.1: Fabless companies are more dependent on core IP and advanced EDA tools than IDMs because of the significance of IP innovation and management.

Proposition 3.2: The highly specialized global supply chain and reliance on a skilled workforce are equally significant for IDMs, foundries, and fabless companies.

4.1.3. Value-oriented

Value & services

Regarding the value and services of these three business models, the following points need to be considered: the products or services sold, the customer problem or need to be solved, and the reasons for buying the products or services (Haaker et al., 2018). Before the first foundry companies emerged, IDMs were predominantly engaged in the production of chips designed by their clients, providing solely their proprietary process technologies, a model known as Customer Owned Tooling (COT) (Saito, 2009). In contemporary contexts, IDMs mainly supply diverse semiconductor products, including microprocessors, memory chips, sensors, and various integrated circuits. Due to their comprehensive control over the production process—from design and manufacturing to packaging and testing—IDMs address supply chain complexities by offering holistic solutions that span design to delivery, thereby fulfilling customer demands. Customers' choice of IDMs is often based on their reliability, the comprehensiveness of their services, and the continuity of their supply.

Fabless companies, in contrast, derive significant advantages from their concentrated focus on technological capabilities and the efficiency of their product platforms (J. H. Park et al., 2018). This strategic focus enables them to specialize in the design of high-performance chips for a range of applications, including mobile devices, automotive technologies, and consumer electronics. Fabless firms are characteristically deeply involved in developing IP, as their business model relies on creating innovative, high-value chip designs that can be manufactured at external foundries. The direct value they offer to customers lies in their capacity for innovation and specialization in chip design, which caters to the escalating demand for novel, custom semiconductor technologies. Compared to IDMs, fabless companies are able to introduce advanced performance features in chip design more rapidly, thus positioning themselves as a preferred choice for customers.

Foundries primarily provide semiconductor manufacturing services to fabless companies, focusing exclusively on production aspects. This specialization allows fabless companies to actualize their chip designs without investing in or managing costly and complex manufacturing facilities. The selection of foundries by customers is motivated by the foundries' advanced manufacturing capabilities and scalability. Moreover, foundries achieve significant manufacturing and cost efficiencies through economies of scale, offering substantial benefits to customers by reducing product costs, enhancing performance, and accelerating market entry (M. Chang, 2007).

Proposition 4.1: Vertical integration enables IDMs to provide holistic solutions while maintaining reliable, continuous, and high-quality semiconductor products for customers who are seeking a single-source solution.

Proposition 4.2: Both fabless and foundry focus on efficiency; the collaboration of these two business models enables the production of semiconductor products at lower costs with faster time-to-market due to the innovative, specialized nature of fabless and scalability, technological expertise of the foundry.

4.1.4. Demand-oriented

Customer relationships

IDMs focus on general-purpose microprocessors and cater to a concentrated market of major clients (Olivieri, 2020). Close and direct interactions characterize the relationships maintained with these clients. Given their complete control over the entire production process, IDMs can offer highly customized solutions. This capability allows them to tailor their technologies and end products to meet the specific needs of individual customers, especially in areas where specialized semiconductor solutions are crucial.

Fabless companies primarily engage with the high-end electronics sector. These firms sustain robust, innovation-driven interactions with their end customers (Olivieri, 2020). However, customer loyalty in this segment tends to be relatively low, a phenomenon attributable to the industry's dependence on continuous innovation for profitability and sustainability. Fabless companies are known for their ability to provide highly customized design solutions tailored to customer specifications, producing specialized chips for applications such as mobile devices, automotive systems, or IoT devices.

On the other hand, foundries are mostly engaged in the manufacture of chips based on designs provided by their clients. While they do not traditionally engage in product customization, foundries offer a range of process technologies and manufacturing capabilities. Strategic partnerships and long-term contracts with fabless companies often lead to more personalized interactions, mainly when it involves aligning foundry capabilities with the technological needs of their clients. Therefore, customization in the foundry business model can be considered at the process level rather than at the product level, focusing on adapting manufacturing processes to fit the precise requirements of client designs.

Proposition 5.1: IDMs and foundries maintain close and direct interactions with their loyal clients, whereas fabless has low customer loyalty because of its innovation-driven feature.

Channels

IDMs typically utilize direct sales teams to interface with substantial clients while increasingly integrating digital platforms into their communication strategies. Using Intel as an illustrative case, the firm combines traditional marketing techniques with digital strategies, enabling it to engage effectively with its target clients across various touchpoints and reinforce key messages robustly (Urrutia, 2024). Concerning distribution channels, Intel exclusively employs authorized distributors to market its products. Amidst the heterogeneous market landscapes across regions such as Europe, North America, and China, IDMs strategically tailor their sales approaches to conform to the local market dynamics, which includes the use of both online and offline channels to maximize market penetration and align with regional consumer preferences (Bauer, 2020).

Since fabless companies do not have manufacturing facilities, they rely on strategic collaborations with foundries to produce their chip designs. This operational model needs an extended distribution strategy that leverages partnerships with foundries and third-party logistics providers to ensure efficient delivery and handling of their products. Additionally, these firms significantly emphasise developing strong business-to-business (B2B) relationships, which is helpful for customised projects that require intensive cooperation during the design phase to ensure that both the technical and commercial objectives are met. Additionally, strategic negotiations and contractual agreements serve to secure advantageous terms that strengthen supply chain dependability and sustain competitive advantage.

Foundries, due to their role differences from IDMs, access market demand information through distinct channels: foundries focus strictly on manufacturing, while IDMs interact with supply chain participants closer to the end market (Q. Li & Zhou, 2019). For example, IDMs like IBM and HP routinely request sales data from dealers, a resource not available to foundries (H. Lee & Whang, 2002). This often results in IDMs having a better understanding of market demands (Z. Li et al., 2014). For instance, TSMC primarily uses direct sales channels to engage with customers and collaborates with industry associations and research institutions for promotion while also employing online platforms and digital marketing strategies to expand market coverage and communicate with customers (Murtaza, 2024).

Proposition 6.1: IDM, fabless and foundry all focus on developing B2B relationships.

Proposition 6.2: IDMs understand market demand better than foundries due to their closer interactions with supply chain participants and end markets.

Customer segments

IDMs primarily serve large original equipment manufacturers (OEMs), technology companies, and sometimes even end consumers of certain products such as microprocessors and sensors. For instance, Intel, a leading IDM, principally supplies OEM computer manufacturers such as Dell and Lenovo, which produce branded computing devices. As per data from 2023, a significant portion of Intel's revenue, approximately 40%, is derived from three primary customers: Dell, Lenovo Group, and HP (Intel, 2023b).

Fabless companies target technology areas that require specific high-performance semiconductor chips, such as the mobile device, automotive electronics, and consumer electronics industries. Its customer base is characterized by those seeking innovative and highly specialized semiconductor solutions and who value short lead times and design flexibility. Typically, these are technology-intensive industries such as OEMs and Tier 1 suppliers in the industries mentioned above.

Foundries primarily serve fabless semiconductor companies, but also IDMs that outsource some of their production needs when their capacity is insufficient. Its customer segment requires state-of-the-art manufacturing capabilities but also scalability and production reliability.

Proposition 7.1: Compared to IDM companies, where relationships with large OEMs dominate customer segmentation, fabless companies experience higher customer turnover rates.

4.1.5. Financial-oriented

Cost structure

The semiconductor industry is characterized by being technologically-intensive and capital-intensive; thus, IDM, as a major player, has to invest heavily in research and development to stay competitive. Given the rapid pace of technological advancement in this industry, R&D is a substantial and ongoing expense necessary to innovate and improve product offerings. IDMs have to sustain huge fixed costs to build fabs, and the cost of running a fab is drastically increasing (Olivieri, 2020). The cost of manufacturing consists of Capital Expenditure (CapEx) and Operational Expenses (OpEx). Fabs require specialized equipment for lithography, deposition, etching, and other chip fabrication processes, as well as the costs of running fabrication facilities such as energy consumption, maintenance of equipment, raw materials, and labour costs, which are extremely expensive. On the other hand, costs associated with patenting new technologies and licensing fees paid to other companies for using their technologies are included.

R&D is a major expense for fabless companies, as their business model centres around innovation in chip design. These costs include the employment of design engineers, expenditures on design software, testing equipment, and costs related to prototyping and validating designs. Although fabless companies do not incur the capital expenditures associated with building and maintaining fabrication facilities, they do pay foundries to manufacture their chip designs.

Foundries require substantial capital investments to build and equip manufacturing facilities. These facilities, or fabs, are outfitted with highly specialized, expensive equipment necessary for semiconductor manufacturing. Moreover, running the foundry involves operational expenses, such as material costs, labour costs, and maintenance. Though foundries primarily focus on manufacturing, they also have R&D costs to improve manufacturing processes and yield efficiencies. The foundry is also in charge of the packaging and testing phases, ensuring the chips meet client specifications through rigorous quality control and testing processes, which incur additional costs.

Proposition 8.1: IDM faces a unique cost structure in its operations, with high fixed and variable costs.

Proposition 8.2: The Fabless-foundry collaboration model offers a more flexible and cost-effective approach to semiconductor production than the vertically integrated IDM model.

Revenue stream

IDMs such as Samsung, Intel, and NXP Semiconductors have crafted diversified revenue streams that exploit their robust capabilities in design and manufacturing. These firms strategically segment their income to span a variety of technology-driven markets, thereby enhancing their market stability and reach. Samsung, for instance, derives substantial revenue from its Consumer Electronics, IT & Mobile Communications, and Device Solutions segments, indicating its broad engagement across diverse consumer and technological domains (Larsen, 2024). Similarly, Intel's revenue structure is anchored in platform sales, which include the Client Computing Group, Data Centre Group, and IoT Group, augmented by additional income from software and services and other emerging technologies. This segmentation highlights Intel's ability to integrate and bundle critical components such as CPUs with chipsets—simplifying customer systems and accelerating time-to-market—and illustrates its strategic dominance and comprehensive integration approach.

Furthermore, Intel's method of bundling products to offer one-stop solutions typifies IDM strategies designed to foster consumer dependence and streamline the purchasing experience (Olivieri, 2020). According to the Dutch Semiconductor Industry Value Chain Overview, the IDM segment grew by 32% in worldwide revenues, mainly due to NXP, comprising 29% of the total sector growth in 2021 (Netherlands Enterprise Agency, 2022). NXP Semiconductors presents comparable diversity, generating major revenues from sectors poised for high growth, including Automotive, Industrial & IoT, Mobile, and Communications Infrastructure. Such strategic diversity and specialization across multiple advanced technological sectors permit IDMs to effectively utilize their extensive research and development along with manufacturing infrastructure to meet broad market demands.

Most fabless companies derive their core revenue from selling semiconductor chips that they design but are manufactured by foundries (Kuan & West, 2021). These chips are widely used in industries with leading technology and high-profit margins, including more specialized applications such as electronic equipment, automotive electronics and industrial machinery (Olivieri, 2020). In addition, fabless companies develop proprietary technologies that can be licensed to OEMs and even IDMs. This includes licensing their IP cores, software, and technology patents.

Proposition 9.1: IDM is able to leverage diversified revenue streams from various technology and consumer markets to enhance stability and expand its market reach.

4.2. Proposition summary from Business Model Canvas analysis

The following propositions outlined in the comparative analysis summarise the key differences between IDM, fabless, and foundry business models. These propositions are detailed in Table 4.2, synthesising how these models operate and interact within the semiconductor ecosystem.

Table 4.2: Proposition summary by orientation and element from comparative analysis

Orientations	Elements		Propositions
Supply and resource-oriented	Key partners	1.1	IDMs and foundries rely heavily on long-term partnerships with suppliers of advanced manufacturing equipment and raw materials, whereas fabless companies primarily depend on collaborative relationships with foundries and IP vendors.
		1.2	The relationships between fabless companies and foundries are characterized by a non-competitive, complementary, and mutually beneficial collaboration, while the relationship between fabless companies and IDM is competitive regarding market share and technological advancement.
	Key activities	2.1	The breadth of business covered by the cooperative model between fabless companies and foundries basically matches the business scope traditionally covered by IDMs without the need for vertical integration.
	Key resources	3.1	Fabless companies are more dependent on core IP and advanced EDA tools than IDMs because of the significance of IP innovation and management.

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Orientations	Elements		Propositions
		3.2	The highly specialized global supply chain and reliance on a skilled workforce are equally significant for IDMs, foundries, and fabless companies.
Value-oriented	Value & services	4.1	Vertical integration enables IDMs to provide holistic solutions while maintaining reliable, continuous, and high-quality semiconductor products for customers who are seeking a single-source solution.
		4.2	Both fabless and foundry focus on efficiency; the collaboration of these two business models enables the production of semiconductor products at lower costs with faster time-to-market due to the innovative, specialized nature of fabless and scalability, technological expertise of the foundry.
Demand-oriented	Customer relationships	5.1	IDMs and foundries maintain close and direct interactions with their loyal clients, whereas fabless has low customer loyalty because of its innovation-driven feature.
	Channels	6.1	IDM, fabless and foundry all focus on developing B2B relationships.
		6.2	IDMs understand market demand better than foundries due to their closer interactions with supply chain participants and end markets.
	Customer segments	7.1	Compared to IDM companies, where relationships with large OEMs dominate customer segmentation, fabless companies experience higher customer turnover rates.
Financial-oriented	Cost structure	8.1	IDM faces a unique cost structure in its operations, with high fixed and variable costs.
		8.2	The Fabless-foundry collaboration model offers a more flexible and cost-effective approach to semiconductor production than the vertically integrated IDM model.
	Revenue stream	9.1	IDM is able to leverage diversified revenue streams from various technology and consumer markets to enhance stability and expand its market reach.

4.3. C-STOF model analysis of Intel, AMD and TSMC

4.3.1. Customer value (C)

Intel's created customer values, market segments and market share

Intel emphasizes customer value through seven key aspects: Customer First, Fearless Innovation, Results Driven, One Intel, Inclusion, Quality, and Integrity (Intel, 2024a).

The company's commitment to customers is the first concern, as it actively listens to and anticipates customer needs. Intel is trying to enhance customer satisfaction and loyalty through quick actions, nurturing partnerships, and fostering continuously evolving ecosystems. As a typical IDM in the rapidly iterating semiconductor industry, ”Fearless Innovation” is at the core of Intel's strategy. This approach enables Intel to maintain a leadership position in competitive markets by continuously enhancing and adapting to changes and opportunities. Regarding ”Quality,” Intel is devoted to maintaining the highest standards in its products and services, ensuring reliability and security that customers and partners can depend on.

As an IDM model, it is notable that Intel maintains long-term, loyal and stable customer and supply chain relationships by focusing on quality control and continuous innovation.

Intel's revenue is diversified across several segments, reflecting its expansive market approach and innovation strategy, which primarily comprised of Client Computing, Data Centre and AI, Network and Edge, Non-volatile memory solutions group, Internet of Things group, etc. (Intel, 2024e). Figure 4.1 shows the revenue by segment of Intel.

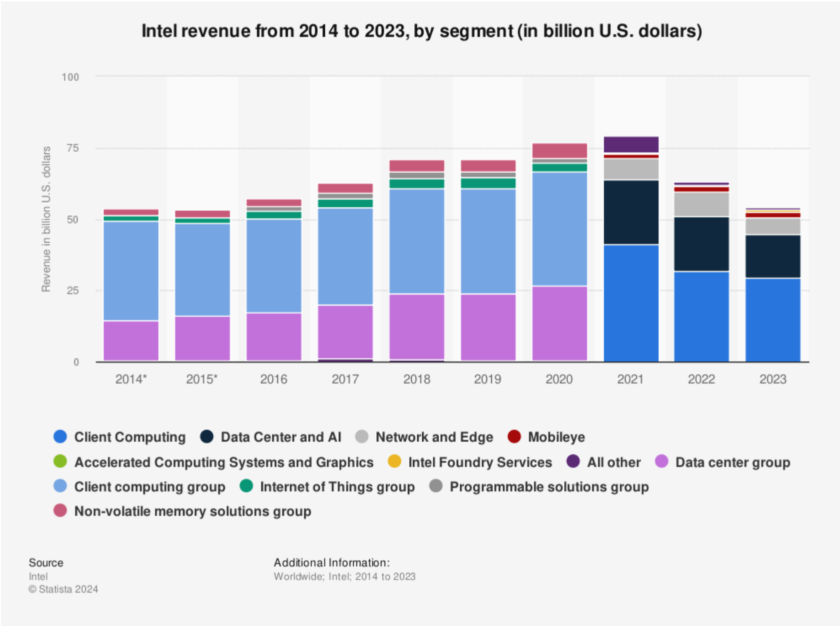

Figure 4.1: Intel revenue from 2014-2023, by segment (in billion U.S. dollars), Intel (2024e)

Client Computing, such as desktop and server CPUs, has always been Intel's traditional business and contributes to the largest share of the market segment. However, there is a visible decrease in its share in the total revenue from 34.87 billion USD in 2014 to 29.26 billion USD in 2023. The Data Centre and AI segment showed growth, especially from 2014 to 2019, aligning with the global expansion in data centre services and AI development, while there has been a decline from 22.77 billion USD in 2021 to 15.52 billion USD in 2023.

Intel's market share in the semiconductor industry has shown notable fluctuations over the past fifteen years. Starting with a 13.30% share in 2008, it peaked at 16.50% in 2011 and maintained a relatively stable presence around 15-16% until 2020. However, there has been an apparent decline in the last few years, dropping to 9.10% in 2023. The data on the revenue share of Intel is presented in the first sub-figure of the C-STOF dashboard Figure 4.4 at the end of this section.

In recent years, Intel's decline in market share could be attributed to increased competition from other fabless semiconductor companies and shifts in market demands favouring other technologies or providers. For example, according to the data from Gartner (2024b), AMD's market share has increased to 4.20% in 2023 compared to 2.7% in 2021. The reasons behind the decline in market share and the transfer of the focus to other segments will be elaborated on and analyzed in Intel's case study.

AMD's created customer values, market segments and market share

AMD is a leader in high-performance and adaptive computing, with a value focus on delivering high-performance, cost-effective, energy-efficient, secure and compatible computing solutions to meet the needs of a variety of users (AMD, 2024a). Its technologies are driving the future of data centres, embedded systems, gaming, and PC markets.

As a leading fabless company in the logic semiconductor industry, AMD's focus on research, innovation, and quality underscores the need for fabless firms that lack production and manufacturing capabilities to prioritize IP cores, innovative design, and strategic customer partnerships.

According to the data of the fourth quarter and full year 2023 financial results published by AMD (2024d), AMD's core business is divided into four parts: data centre, game, client, and embedded. Data presents the data centre segment has always constituted the largest portion of AMD's revenue, attributed to the growing demand for cloud computing and AI technology in recent years. The gaming and client segments also made significant contributions, reflecting AMD's influence in the gaming market and personal computing.

AMD has shown significant revenue growth over the past two decades, as shown in Figure 4.2, with significant growth in the past few years in particular. Starting with revenue of $3.892 billion in 2001, it has fluctuated over the years, with a significant decline around 2012 due to its decision to transform to a fabless model in 2009. Significant growth began in 2019, reaching a peak of $23.601 billion in 2022.

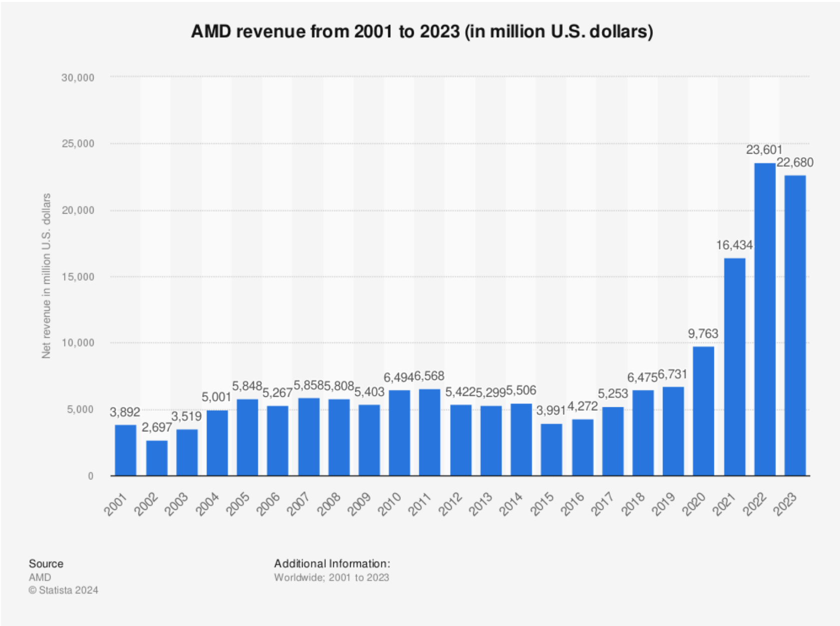

Figure 4.2: AMD revenue from 2001 to 2023 (in million U.S. dollars), AMD (2024c)

The subsequent chapter's case study on AMD, which started in client computing similar to Intel, will deeply explore and analyse the factors contributing to its tremendous revenue growth in recent years, the reasons leading the data centre business to become its primary revenue source, and causing the company's revenue fluctuations from 2001 to 2017.

TSMC's created customer values, market segments and market share

TSMC's core values are integrity, commitment, innovation, and customer trust. These core values underpin TSMC's strategies and operations, ensuring ethical behaviour, commitment to stakeholders, continuous innovation, and strong customer relationships (TSMC, 2022).

Integrity is TSMC's most fundamental core value. The company emphasizes honesty and transparency in all transactions. TSMC maintains objectivity, consistency, and impartiality in supplier interactions, with zero tolerance for corruption or political manipulation. Innovation grounds TSMC's growth, influencing every aspect of its operations, including strategic planning, marketing, management, technology, and manufacturing. Finally and similarly, at TSMC, customers come first. The company views its customers' success as its own and is committed to building deep, enduring relationships. Customers trust TSMC to contribute to their long-term success.

The non-competitive stance and the value of integrity facilitate and enable TSMC, as a foundry, to possess loyal and long-term relationships with fabless companies and suppliers, while its innovation-driven nature of focusing on the development of advanced process technologies contributes to the success of TSMC.

TSMC is currently the world's first and largest integrated circuit foundry. Its primary business involves providing advanced process services to numerous IC design companies using cutting-edge manufacturing technology. In 2023, TSMC's market segments and strategic focus areas are shown in Figure 4.3.

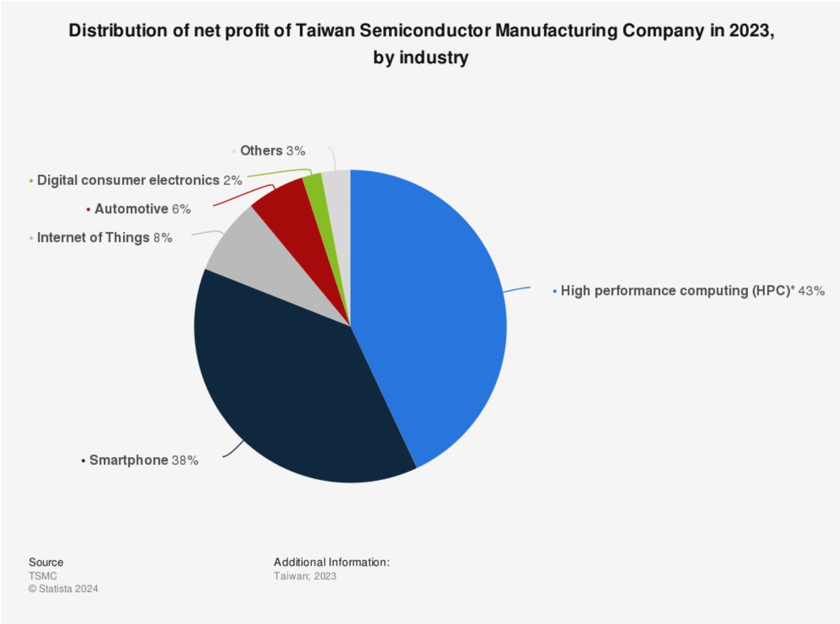

Figure 4.3: Distribution of net profit of Taiwan Semiconductor Manufacturing Company in 2023, by industry, TSMC (2024e)

The semiconductor foundry services for high-performance computing (HPC) and smartphones together account for over 80% of the company's net profit. The emphasis on HPC aligns with the growing demand for advanced computing solutions. In the smartphone communications chip sector, major customers include companies in the mobile technology field, such as Apple, MediaTek, Qualcomm, and Broadcom. According to data collated by Zohaib (2021), Apple's revenue share for TSMC was 25.93%, MediaTek 5.8%, Qualcomm 3.9%, and Broadcom 3.77%. Although the IoT and automotive sectors are smaller in scale, they indicate TSMC's strategic investments in emerging markets to ensure future growth and diversification.

From 2019 to 2023, TSMC maintained a strong and stable market share in the global semiconductor foundry market, the third sub-figure in Figure 4.4, demonstrating significant dominance over its competitors. During this period, TSMC consistently held over 50% of the market share. Samsung, as the second-largest player, is significantly behind TSMC. As of the fourth quarter of 2023, TSMC held the largest market share, significantly ahead of other major players such as GlobalFoundries and UMC.

The following case study of TSMC, assisted by AMD's case, will focus on explaining its high market share in high-performance computing, the significant contribution of its top ten key customers, and the factors that make its foundry business far surpass other foundries.

C-STOF dashboard of customer value

The following Figure 4.4 provides a visual comparison of the core values, market segments and market shares of Intel, AMD and TSMC. The differences and common coverage points between the three in core customer value and market segments provide certain directions and themes for the specific case study in the next chapter. The changes in their market share are the result of the combined effects of the market segments they focused on and corporate core values to a certain extent. These combined effects will be pointed out in the cross-case studies.

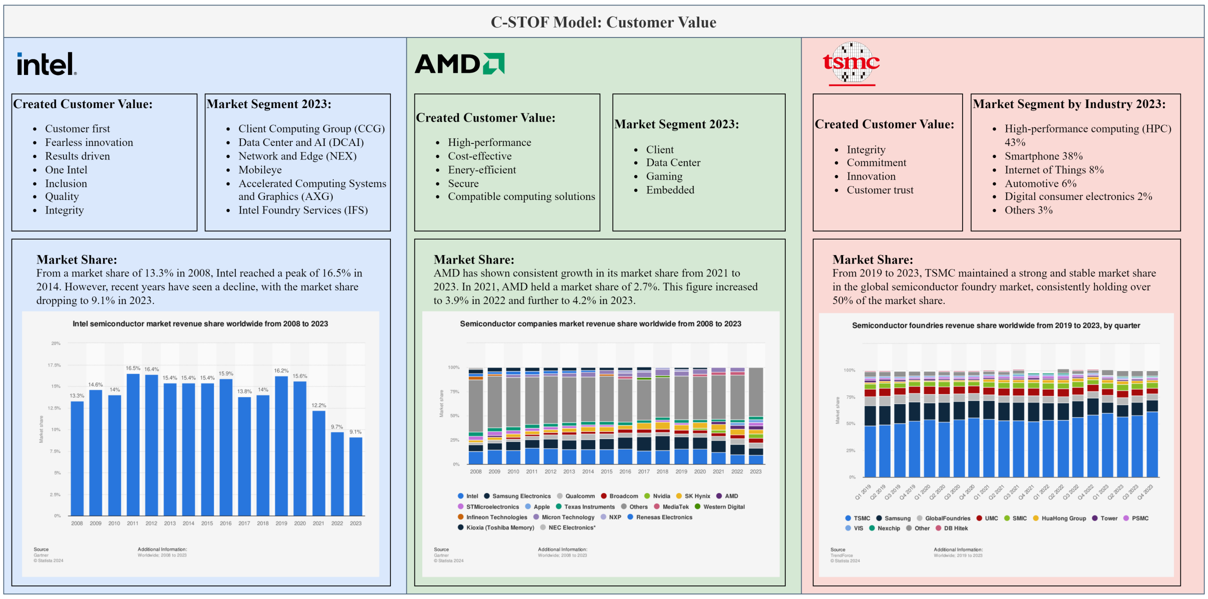

Figure 4.4: Comparison of customer value and market segment and share of Intel, AMD and TSMC, Data source: Intel semiconductor market revenue share worldwide from 2008-2023, Gartner (2024a), Semiconductor companies market revenue worldwide from 2009 to 2023, Gartner (2024b), Semiconductor foundries revenue share worldwide from 2019 to 2023, by quarter, TrendForce (2024)

4.3.2. Service (S)

Intel's product development cycle, quality control, satisfaction and sustainability

Intel's product development cycle, known as the Unified Product Life Cycle (UPLC), supports a wide range of market segments, from silicon products such as CPUs and FPGAs to more complex systems and software products (Intel, 2021). UPLC is divided into five key stages: Concept, Feasibility, Execution, Production, and Post-Production, as shown in the first sub-figure in Figure 4.6. Each stage must meet specific acceptance criteria and receive management approval before moving on to the next stage.

During these stages, the product undergoes rigorous testing, verification, and qualification to ensure that it meets various standards such as manufacturability, reliability, performance, and compliance with safety and security standards. The qualification process can be used to reduce risks associated with logic errors or processor errors. Ultimately, what is learned from the product is passed through a feedback loop to improve the execution of future product life cycle risks and issues.

Quality as one of Intel's seven core values, the quality management system proposed by Intel is the basis for achieving customer satisfaction and continuous improvement, which includes five main processes (Intel, 2021): product development, technology development, manufacturing, Supply chain and customer support.

Intel proactively addresses customer churn by deploying machine learning solutions, as exemplified by their customer churn prediction reference kit developed in collaboration with Accenture (Intel, 2024g). This initiative is part of Intel's broader strategy to enhance customer retention by identifying early indicators of customer attrition using advanced analytics. By implementing predictive models, Intel aims to enable proactive customer interventions, which can improve overall customer satisfaction and reduce churn rates. This approach helps retain customers and reduces the costs of acquiring new ones, thereby enhancing the company's sustainability in customer relationships.

AMD's product development cycle, quality control, satisfaction and sustainability

After its transformation, AMD became a fabless company, meaning it does not have its own manufacturing facilities. To establish quality and reliability from the outset, AMD employs Design for Manufacturability (DfM) and Design for Testability (DfT) principles in its design and development process to ensure the manufacturability and testability of packaged devices(AMD, 2024a). DfT aims to detect problems and identify root causes quickly. At the same time, DfM focuses on reducing risks and optimizing operational excellence to improve quality, reliability, and time-to-market. Simultaneously, AMD adopts Design for Reliability (DfR) to overcome the decreasing reliability margins of advanced process nodes, addressing the needs of highly reliability-sensitive sectors such as data centres, automotive, and aerospace.

Throughout the product cycle, AMD uses a strictly controlled stage-gate process to ensure that each stage meets standards before progressing to the next phase. AMD's product lifecycle management process, as seen in Figure 4.5, helps verify that the entire lifecycle, from product launch to end-of-life, adheres to industry-standard guidelines (AMD, 2024a).

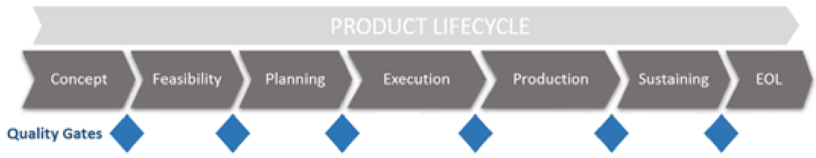

Figure 4.5: AMD product lifecycle, AMD (2024a)

The Chairman and CEO of AMD, Dr. Lisa Su, emphasized that AMD consistently strives to increase customer value by ensuring that quality is an integral part of all their operations (AMD, 2019). AMD delivers high-quality products through its quality management system, containing a range of standards, processes, and systems across the enterprise, emphasizing maintaining quality stability while continuously driving technological innovation. In addition, AMD places great importance on highly differentiated customer collaborations and partnerships, creating innovative, trend-setting, and feature-rich solutions, ensuring product quality through excellent suppliers, adhering to consistent standards and processes, fostering the company's ability to learn and improve continuously, and measuring customer satisfaction to identify ways for enhancement.

AMD is committed to sustainability, particularly in data centres, which contribute a large portion of its market segments, by enhancing server energy efficiency and reducing total cost of ownership (TCO). The company aims to increase the energy efficiency of its processors and accelerators by 30 times from 2020 to 2025, significantly surpassing industry trends (AMD, 2024a). This effort contributes to reducing global energy consumption and greenhouse gas emissions. AMD's HPC initiatives support scientific research and AI development, benefiting numerous institutions and millions of people. Through these efforts, AMD reduces the environmental impact of computing and promotes sustainable practices in data centre operations.

TSMC's service development cycle, quality control, satisfaction and sustainability

TSMC's production cycle is a comprehensive and integrated process that ensures efficient and sustainable manufacturing of advanced semiconductor products. The service cycle involves six key stages: raw material production, wafer manufacturing, testing and packaging, Information and Communications Technology (ICT) product assembly and sales, ICT product Use, and waste management and recycling TSMC (2024g). Each stage focused on maintaining high standards of operational efficiency while incorporating environmental responsibility.

TSMC is dedicated to providing exceptional semiconductor manufacturing services to global customers and establishing mutually beneficial long-term partnerships. TSMC adheres to international quality standards, including ISO 9001, Ford Q1 Award, QS-9000, ISO/TS 16949, and IECQ QC 080000 (TSMC, 2024c). These standards form the foundation of TSMC's quality system infrastructure. TSMC's quality management system is built around core processes such as semiconductor process technology R&D, wafer manufacturing, customer service, design services, mask-making, wafer probing, bumping, and testing (in-house or outsourced) TSMC (2024c).

Furthermore, as a pure-play foundry, manufacturing is TSMC's sole and primary business. The company has developed manufacturing defence systems and implemented necessary measures for raw materials and supply chain risk management, as well as operational accuracy and efficiency management (TSMC, 2024c).

TSMC is intended to provide the best service to its customers, believing that customer service is crucial for enhancing customer loyalty. In turn, customer loyalty leads to higher levels of customer retention and expanded business relationships (TSMC, 2013). TSMC regularly conducts surveys and reviews to ensure a comprehensive understanding of and fulfil customer needs and desires. Complemented by customer feedback, continuous improvement plans are indispensable to TSMC's business processes. According to the annual customer satisfaction ratings provided by Statista from 2015 to 2022, as illustrated in the second sub-figure in Figure 4.6, TSMC has consistently demonstrated high levels of customer satisfaction over the years. This reflects TSMC's commitment to delivering exceptional service and maintaining strong customer relationships.

As mentioned in the production cycle, TSMC considers Environmental, social, and governance (ESG) factors, adhering to responsible business conduct such as reducing greenhouse gas emissions, pollution prevention, hazardous substance management, and assessing product carbon/water footprints (TSMC, 2024g). TSMC focuses on high-quality semiconductor manufacturing while minimizing environmental impact and promoting sustainability. These behaviours reinforce its position as a leader in the semiconductor industry.

C-STOF dashboard of service

Figure 4.6 shows the comparison of the product or service development cycle, quality control, sustainability and satisfaction of Intel, AMD and TSMC. The overlapping emphasis of the three business models on product and service quality control reflects the significance of product quality in the semiconductor industry in improving customer satisfaction, maintaining long-term customer partnerships, and enhancing corporate sustainability. However, due to the different natures of IDM and fabless companies, Intel, as a vertically integrated IDM, has independent design capabilities and production facilities that can cover the entire front-end life cycle of semiconductor products, while fabless companies such as AMD rely on the manufacturing capabilities of foundries, hence, they are actually uncontrollable in the production and manufacturing process.

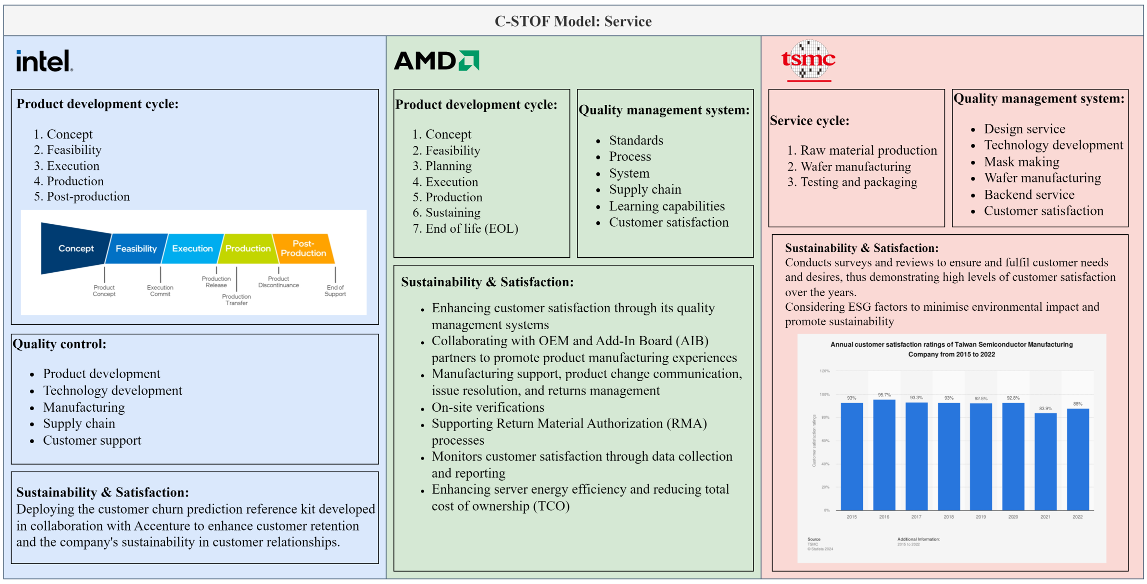

Figure 4.6: Comparison of product cycle, quality, satisfaction and sustainability of Intel, AMD and TSMC, Data source: Intel Unified Product Lifecycle (UPLC), Intel (2021)
AMD's Customer Quality AMD (2024a),
Product life cycle environmental / Social impacts consideration, TSMC (2024g),
Annual customer satisfaction ratings of Taiwan Semiconductor Manufacturing Company from 2015 to 2022, TSMC (2023a)

4.3.3. Technology (T): Architectural complexity

Intel's technological architecture and interoperatability

Although Intel is renowned for its PC processors, its technology spans nearly every electronic domain, including automotive, industrial, automation, robotics, military, and medical industries (Intel, 2023a). Intel's architecture supports a wide range of applications, from consumer electronics to high-performance computing, showcasing the versatility of its platforms. The architecture features highly integrated building blocks that simplify system design while continuously innovating its microarchitecture to enhance performance, energy efficiency, and integration capabilities. This includes advancements in transistor design, direct integration of AI capabilities into the silicon, and optimization for specific workloads.

Intel's platforms cover a range of functionalities, performance levels, and power tiers, allowing for the reuse of software and tools across generations and product lines (Intel, 2023a). The scalability and security of Intel platforms enable them to support devices from the Internet of Things (IoT) to data centres. Notably, Intel's Xeon and Core series exemplify this scalability, catering to both enterprise-grade servers and personal computers (Intel, 2024f). With data centres accounting for approximately 20% of Intel's total revenue, optimizing data centre performance and energy efficiency remains a key focus of Intel's investment in cloud technologies, as their processors are central to many cloud infrastructure setups.

Furthermore, Intel is actively enhancing interoperability within the manufacturing sector through its support for Industry 4.0 and smart manufacturing (Intel, 2024c). By integrating information technology (IT) and operational technology (OT) systems into a unified computing platform, Intel facilitates a responsive, interconnected system that eliminates data silos and enhances flexibility and control with edge computing. This approach supports real-time operational adjustments, predictive maintenance, and advanced analytics, reducing downtime and optimizing operations. Intel's dedication to open architectures and standards-based solutions further supports seamless interoperability across diverse industrial environments.

AMD's technological architecture

The introduction of the Zen architecture in 2016 marked a turning point for AMD's competitiveness in the CPU market. This architecture's design philosophy emphasizes outstanding performance, remarkable scalability, and exceptional energy efficiency (AMD, 2024a). Each iteration of the Zen architecture, from Zen 1 to Zen 4, has utilized advanced process nodes (ranging from 14nm to 4nm), significantly improving instructions per clock (IPC) and power efficiency (Subramon et al., 2023). A key innovation within the Zen architecture is the Chiplet design introduced with Zen 2, which separates core logic from I/O components into distinct Chiplets connected by AMD's Infinity Fabric (Naffziger et al., 2020). This modular approach enhances scalability, manufacturing efficiency, and cost-effectiveness, which is crucial for a fabless company like AMD that relies on third-party foundries such as TSMC. The architectural advancements within the Zen framework have enabled AMD to offer a diverse product lineup, from high-end desktop CPUs Ryzen to powerful server processors EPYC and mobile solutions, effectively addressing various market segments and adapting to changing demands.

TSMC's technological architecture

TSMC has consistently maintained robust internal R&D capabilities, providing the most advanced and comprehensive specialized foundry process technology portfolio. As process technologies advance, the continuous reduction in IC linewidth presents significant manufacturing challenges, requiring stricter process and quality controls. TSMC's unique manufacturing architecture is fitted to manage a diverse product range, utilizing rigorous process controls to enhance product quality and meet higher customer demands for quality, performance, and reliability (TSMC, 2024d). TSMC's process control system incorporates various intelligent functions to achieve excellence in manufacturing and product quality. Through Intelligent Detection, Smart Diagnosis, and Cognitive Action, TSMC excels in improving yield, ensuring quality, enhancing processes, detecting errors, reducing costs, and shortening development cycles (TSMC, 2024d).

To meet the rigorous quality standards of the 5G era for mobile devices, HPC, automotive electronics, and IoT products, TSMC has integrated AI and machine learning technologies. This integration has resulted in the development of precise fault detection and classification systems, intelligent advanced equipment control, and intelligent advanced process control, enabling precise control over processes and equipment (TSMC, 2024d). Coupled with a knowledge-based engineering analysis system for intelligent process variation detection, TSMC minimizes process variations and potential defects through self-diagnosis and cognitive action mechanisms. This ensures that every chip achieves nanometre-level precision control, delivering the highest quality wafers to customers.

C-STOF dashboard of technology

The following Figure 4.7 shows Intel, AMD and TSMC's respective architectural complexities of their technologies. All three companies underscore employing advanced process nodes and technologies to enhance performance, energy efficiency, and scalability, which embodies the significance of focusing on R&D and innovation in the competitive semiconductor industry. Although Intel, AMD, and TSMC share common goals of advancing process technologies and product diversification, their approaches reflect their distinct business models. Intel's IDM model allows for greater interoperability in design and manufacturing, whereas AMD's fabless model and TSMC's foundry focus lead to specialized innovations within their respective domains. Only IDM companies like Intel possess the ability to integrate design and manufacturing coherently, leveraging their in-house production capabilities, which is difficult for fabless or foundry companies.

C-STOF Model: Technology

intel

Architectural complexity:

1. **Technological Versatility**: Intel's technology extends beyond PC processors to various electronic domains, including automotive, industrial, automation, robotics, military, and medical industries.
2. **Integrated Building Blocks**: Features highly integrated components that simplify system design and improve performance, energy efficiency, and integration capabilities.
3. **Microarchitecture Innovations**: Continuous advancements in transistor design, AI integration into silicon, and optimization for specific workloads.
4. **Platform Scalability**: Supports a wide range of applications, maintaining software and tool reusability across generations and product lines.
5. **Diverse Functionalities**: Platforms cater to different functionalities, performance levels, and power tiers

Interoperability:

1. **Interoperability in Manufacturing**: Supports Industry 4.0 and smart manufacturing by integrating IT and OT systems, enabling real-time operational adjustments, predictive maintenance, and advanced analytics.
2. **Open Architectures and Standards**: Commitment to open architectures and standards-based solutions enhances seamless interoperability across diverse industrial environments.

AMD

Architectural complexity:

1. **Design Philosophy**: Emphasizes outstanding performance, remarkable scalability, and exceptional energy efficiency.
2. **Advanced Process Nodes**: Each Zen iteration (from Zen 1 to Zen 4) has employed advanced process nodes (ranging from 14nm to 4nm), enhancing instructions per clock (IPC) and power efficiency.
3. **Chiplet Design Innovation**: Introduced with Zen 2, this design separates core logic from I/O components into distinct chiplets connected by AMD's Infinity Fabric, enhancing scalability, manufacturing efficiency, and cost-effectiveness.
4. **Diverse Product Lineup**: Architectural advancements have enabled AMD to offer a broad product range, from high-end desktop CPUs (Ryzen) to powerful server processors (EPYC) and mobile solutions, addressing various market segments and adapting to changing demands.

tsmc

Architectural complexity:

1. **Unique Manufacturing Architecture**: Tailored to manage a diverse product range with rigorous process controls, enhancing product quality and meeting higher customer demands for quality, performance, and reliability.
2. **Intelligent Process Control System**: Incorporates Intelligent Detection, Smart Diagnosis, and Cognitive Action to improve yield, ensure quality, enhance processes, detect errors, reduce costs, and shorten development cycles.
3. **AI and ML Integration**: To meet the rigorous quality standards of the 5G era, TSMC has integrated artificial intelligence and machine learning technologies, resulting in precise fault detection and classification systems, intelligent advanced equipment control, and intelligent advanced process control.
4. **Knowledge-Based Engineering Analysis**: Utilizes a system for intelligent process variation detection, minimizing process variations and potential defects through self-diagnosis and cognitive action mechanisms, ensuring nanometre-level precision control for every chip.

Figure 4.7: Comparison of architectural complexity of Intel, AMD and TSMC

4.3.4. Organization (O)

Intel's organizational structure and access to resources

As described in the above market segments, from the perspective of product-type divisions, Intel's operations are segmented into the following six business units starting in the first quarter of 2022: Client Computing Group (CCG), Datacenter and AI Group (DCAI), Network and Edge Group (NEX), Accelerated Computing Systems and Graphics Group (AXG), Intel Foundry Services (IFS), and Mobileye (MBLY) (Intel, 2022b).

Intel comprehensively outlines its strategic approach to resource management in its 2022-23 Corporate Responsibility Report, demonstrating the integration of internal and external capabilities that facilitate operational excellence and sustainability. The company manages a network of over 9,000 first-tier suppliers across more than 85 countries, ensuring a resilient supply chain adapting to global market fluctuations and demand changes (Intel, 2024b). This extensive network guarantees a reliable flow of critical materials and components and supports Intel's commitment to quality and environmental stewardship.

Additionally, Intel's strategic investments in technology and collaborations enhance its internal resource capabilities, increasing the flexibility and responsiveness of its manufacturing operations. Intel's manufacturing facilities primarily fabricate, assemble, and test silicon wafers for platform products. Operating as an IDM, they run within a network of manufacturing facilities integrated as one single factory, providing the most flexible supply capacity (Intel, 2024b). New process technologies are transferred from a central development fab to each manufacturing facility. After the transfer, the network of factories and the development fab collaborate to continue driving operational improvements.

Intel supports those above function-based internal partners through its global supply chain. Moreover, the report emphasizes that Intel's priority is to achieve product and process leadership and industry-leading total cost of ownership, and it even supplements its manufacturing capabilities through third-party foundries (Intel, 2024b).

AMD's organizational structure and access to resources

As a leading fabless semiconductor company, AMD's structure comprises several key departments designed to manage its diverse operations and product lines effectively. Under the leadership of CEO and Chair Dr. Lisa Su, the executive team oversees strategic decisions, technological direction, and financial management. The Computing and Graphics Business Group within the business units focuses on AMD's consumer products, including Ryzen CPUs and Radeon GPUs, managing product development, marketing, and sales to meet the demands of the consumer market (AMD, 2024a). Meanwhile, the Server Business Unit is responsible for EPYC server processors, targeting enterprise and data centre solutions. The Engineering and Technology department handles core engineering functions and the development of all AMD product lines, including the architecture of AMD CPUs and

GPUs (AMD, 2024a). This department's Artificial Intelligence team integrates AI capabilities into AMD products, leveraging technology acquired from Xilinx to enhance products like the Zen 5. Within the Sales and Marketing department, the Global Operations team manages AMD's global supply chain, formulates global sales strategies, and maintains customer relationships, with a focus on regions such as Europe, Middle East, and Africa (EMEA) and Greater China (AMD, 2024a). Lastly, the Support and Operations department ensures high product quality and customer satisfaction standards while overseeing internal processes to improve efficiency and support AMD's strategic goals.

AMD's success largely relies on its extensive business networks and the flexibility to leverage expertise. Without owning manufacturing facilities, AMD depends on partnerships with leading semiconductor foundries such as TSMC, which manufactures AMD's cutting-edge products, including EPYC, Ryzen, and Radeon processors, using advanced 7nm process technology (AMD, 2021). The custom SoC designed in collaboration with AMD also powers the Xbox One gaming console released by Microsoft in 2013, providing robust security and integrity (Mattioli, 2021). AMD maintains strong relationships with OEMs such as Dell, HP, and Lenovo. The new Ryzen PRO 8040 series mobile processors are expected to be offered by OEM partners, including HP and Lenovo, starting from the second quarter of 2024 (MacDiarmid & Bhaskaran, 2024a).

The flexibility of AMD's expertise is also demonstrated through acquisitions such as Xilinx, which aim to provide more computing options optimized for different market segments. AMD is adopting a platform approach to increase its processing revenue share in edge devices, traditional desktops, workstations, and servers (Hou & Schmitt, 2020). Additionally, AMD seeks to enhance its expertise in FPGAs and AI, integrating diverse technological capabilities into its product portfolio.

TSMC's organizational structure and access to resource

For TSMC's core business manufacturing, its organizational structure includes operations, R&D, quality and reliability, information technology, materials management, global sales, business development, and overseas operations offices(TSMC, 2024c).

TSMC's core operations and R&D activities in Taiwan are supported by four 12-inch wafer GIGAFAB® fabs, four 8-inch fabs, one 6-inch fab, five advanced backend packaging and testing plants, and global R&D center. Regarding overseas operations, TSMC has a 12-inch fab in its wholly-owned subsidiary TSMC Nanjing Co., Ltd., and two 8-inch fabs in TSMC Washington, USA and TSMC China Co., Ltd.(TSMC, 2024c). In addition, TSMC provides technical support and services to customers through customer management and engineering service offices worldwide.

TSMC's extensive business network and strategic alliances are among the most powerful innovation forces in the semiconductor industry. NVIDIA's CEO, Jensen Huang, emphasized the importance of collaboration with TSMC at the annual GPU Technology Conference (GTC) NVIDIA (2024) in San Jose, California, stating that the partnership with TSMC is one of their closest partnerships. These partnerships bring together TSMC's customers, EDA partners, IP partners, and key equipment and material suppliers in a highly collaborative ecosystem.

TSMC's Grand Alliance, through the Open Innovation Platform® (OIP), supports customer innovation by helping them maximize the value of TSMC's technology (TSMC, 2024d). This includes specific partnerships with IP partners, EDA partners, the Value Chain Aggregation (VCA) program, and the Design Center Alliance (DCA). TSMC's VCA program enhances its capability to serve a broader range of customers by integrating design support building blocks into TSMC's OIP, providing specific services across every segment of the IC value chain, including IP development, backend design, wafer manufacturing, assembly, and testing (TSMC, 2024d). The DCA partners focus on chip implementation services and system-level design solutions support, aiming to lower the design barriers for customers adopting TSMC technologies (TSMC, 2024d). This alliance network enables complex design solutions to integrate, ensuring customers can utilize TSMC's advanced technologies effectively.

TSMC's vast scale grants it unparalleled benefits in economies of scale and R&D expenditure, allowing the company to offer highly competitive prices and over 10,000 specialized products in advanced markets such as IoT, autonomous vehicles, and high-performance computing (TSMC, 2024a). The dependence of G7 countries on Taiwan's supply chain, particularly on TSMC, is significant. Analysis of global business relationships reported by Geraint (2023) reveals that U.S. companies have nearly 70,000 direct (first-tier) partnerships with Taiwanese suppliers, while other G7 nations collectively have nearly 10,000 direct relationships.

C-STOF dashboard of organization

Figure 4.8 below compares the organizational structures and access to resources of Intel, AMD, and TSMC based on the C-STOF model. Intel's strategic initiatives focus on integrating its manufacturing operations and establishing a foundry services department to address its flexibility challenges as an IDM company. AMD's strategic acquisitions of Xilinx and ATI have significantly supported its technical capabilities and expanded its market reach. These acquisitions are expected to enable AMD to offer a broader range of computing solutions applied to various market segments. Furthermore, AMD's reliance on strategic partnerships with leading foundries, such as TSMC, underscores its ability to leverage external expertise to manufacture advanced products. Additionally, TSMC's extensive collaborative ecosystem, which includes major customers, EDA partners, IP partners, and equipment and material suppliers, fosters innovation and supports the development of cutting-edge technologies. TSMC's economies of scale and considerable R&D investments further enable it to offer various specialized products in advanced markets. These strategic approaches, organizational structures, and corporate resource level highlight critical areas for detailed exploration in the subsequent case analysis section.

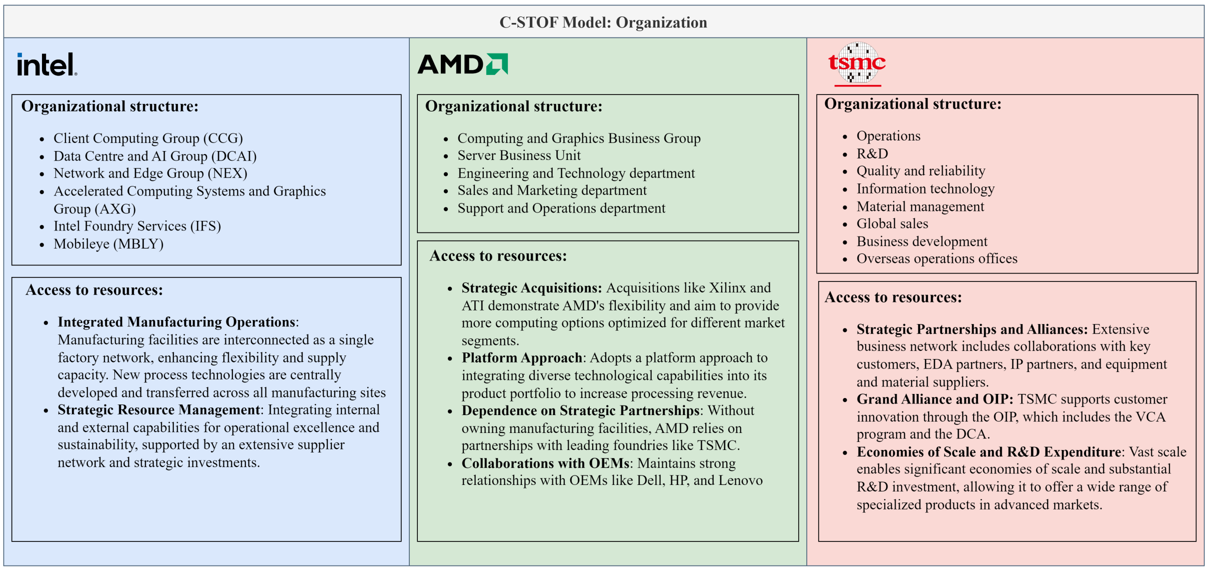

Figure 4.8: Comparison of organizational structure and access to resources of Intel, AMD and TSMC

4.3.5. Finance (F)

Intel's profitability and costs

According to the financial data provided by Macrotrends (2024b), Intel's return on investment has fluctuated significantly over the past three years. From a high of 17.72% in June 2021, it dropped significantly to 0.06% by the end of 2023. Intel's earnings before interest and taxes also fell sharply. In 2021, EBIT was US$19.456 billion, but by 2023, it had fallen to US$93 million, a decrease of 96.02%. Also declining is Intel's net profit, which dropped from US$19.868 billion in 2021 to US$1.689 billion in 2023, a decrease of 78.92%. Intel's revenue fluctuates greatly, reaching a peak of US$79.02 billion in 2021 and falling to US$54.23 billion in 2023 (NasdaqGS, 2024d). Revenue in 2023 decreased by 14.00% compared to the previous year.

Intel's capital expenditures have shown significant fluctuations over the past five years, as shown in Table 4.3. Data shows that In 2019, Capex was $16.213 billion, increasing to a peak of $25.75 billion in 2023. The average Capex over this period was $20.359 billion, with a median of $20.329 billion. The Capex as a percentage of revenue also varied, peaking at 47.5% in 2023, reflecting heavy investments in long-term assets despite revenue fluctuations.

Table 4.3: Fiscal Year Data, NasdaqGS (2024b)

Fiscal Year	Capital Expenditures	Revenue	%Revenue
2019-12-28	$16.213 B	$71.965 B	22.5%
2020-12-26	$14.453 B	$77.867 B	18.6%
2021-12-25	$20.329 B	$79.024 B	25.7%
2022-12-31	$25.05 B	$63.054 B	39.7%

Table 4.3: (continued)

Fiscal Year	Capital Expenditures	Revenue	%Revenue
2023-12-30	$25.75 B	$54.228 B	47.5%

Intel's operating expenses have also experienced changes, reflecting the company's cost management and operational efficiency (Macrotrends, 2024b). For the twelve months ending December 31, 2023, Opex was $54.135 billion, a 10.84% decrease from the previous year. In 2022, Opex was $60.72 billion, slightly higher than 2021's $59.568 billion.

AMD's profitability and costs

AMD's ROI has also varied significantly over the years, according to Macrotrends (2024a)'s data. For the quarter ending December 31, 2023, the ROI was 0.70%, following a negative ROI of -0.16% and -0.66% in the previous quarters of 2023. The highest ROI recorded in recent years was 50.66% at the end of 2021.

For the quarter ending December 31, 2023, AMD reported an EBIT of $0.342 billion, marking a 329.53% year-over-year decline. The company's annual EBIT for 2023 was $0.401 billion, a 68.28% drop from 2022. In 2022, the EBIT stood at $1.264 billion, down from $3.648 billion in 2021, which had seen a 166.47% increase from 2020. This trend indicates AMD's challenges in maintaining profitability amid varying market conditions and competitive pressures.

However, AMD's revenue has grown remarkably, particularly in recent years. For the quarter ending December 31, 2023, AMD reported a revenue of $6.168 billion, a 10.16% increase year-over-year. The annual revenue for 2023 was $22.68 billion, marking a 3.9% decline from the previous year. This follows an impressive revenue of $23.601 billion in 2022, which was a 43.61% increase from 2021. The revenue growth in 2021 was particularly obvious, with a 68.33% increase from 2020, reaching $16.434 billion. Additionally, AMD's net income has experienced fluctuations over the years. In 2023, AMD's net income was $854 million, a significant decrease from $1.32 billion in 2022 and $3.162 billion in 2021, as shown in Figure 4.9.

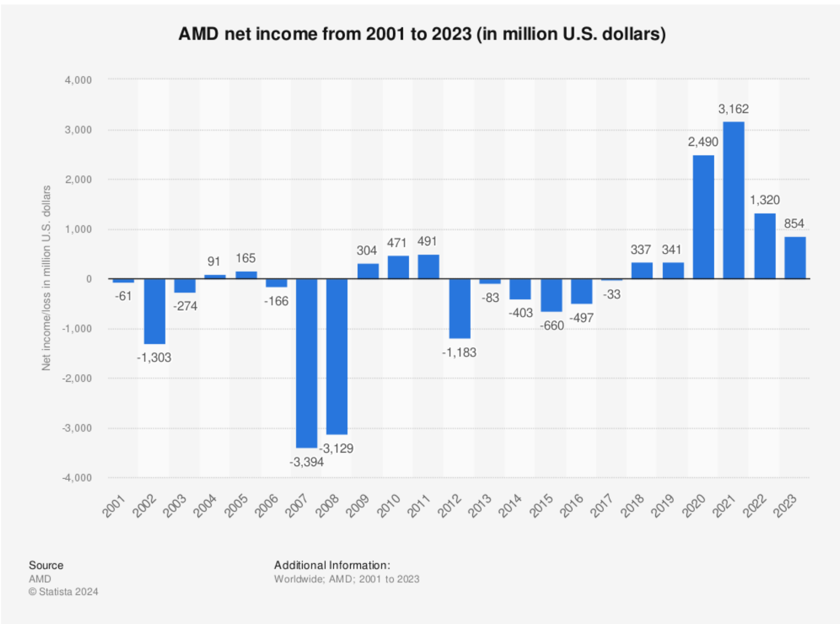

Figure 4.9: AMD net income from 2001 to 2023 (in million U.S. dollars), AMD (2024b)

In 2023, capital expenditures were $546 million, reflecting a 21.33% decrease from the previous year (NasdaqGS, 2024a). This follows a 49.50% increase in 2022, where CapEx was $450 million. The trend over these years shows fluctuating investment in fixed assets, which was $301 million in 2021 and $294 million in 2020. The changes in capital expenditures indicate AMD's strategic allocation of resources to enhance its manufacturing capabilities and infrastructure while adapting to market demands.

AMD's operating expenses have also fluctuated significantly. For the quarter ending December 31, 2023, operating expenses were $5.826 billion, a 1.36% increase year-over-year (Macrotrends, 2024a). The annual operating expenses for 2023 were $22.279 billion, marking a 0.26% decline from the previous year. In 2022, AMD's operating expenses were $22.337 billion, a substantial 74.7% increase from $12.786 billion in 2021. The significant rise in operating expenses in recent years reflects AMD's investment in research and development, marketing, and administrative costs to support its growth and competitive strategy.

TSMC's profitability and costs

The ROI data of TSMC from March 2021 to March 2024 shows a fluctuating trend. As of March 31, 2024, TSMC's ROI was 21.56%, a decline from previous quarters but still indicative of substantial profitability (MacroTrends, 2024). ROI peaked at 31.68% on December 31, 2022, highlighting a period of significant financial performance.

TSMC's EBIT history reflects solid financial performance with fluctuations due to varying market conditions. For the quarter ending March 31, 2024, the EBIT was $7.919 billion, a 4.09% increase year-over-year (MacroTrends, 2024). The annual EBIT for 2023 was $30.094 billion, a 17.52% decline from 2022, which had an EBIT of $36.488 billion, showcasing a significant growth of 55.72% from 2021's $23.431 billion.

TSMC has consistently achieved high net profits, as illustrated in the graph 4.10 from 2015 to 2023. The net profit for the year ending December 31, 2023, was $837.77 billion NTD, a decrease from the record high of $1,016.9 billion NTD in 2022. Despite the recent decline, TSMC has shown strong profitability, with net profits rising from $306.57 billion NTD in 2015.

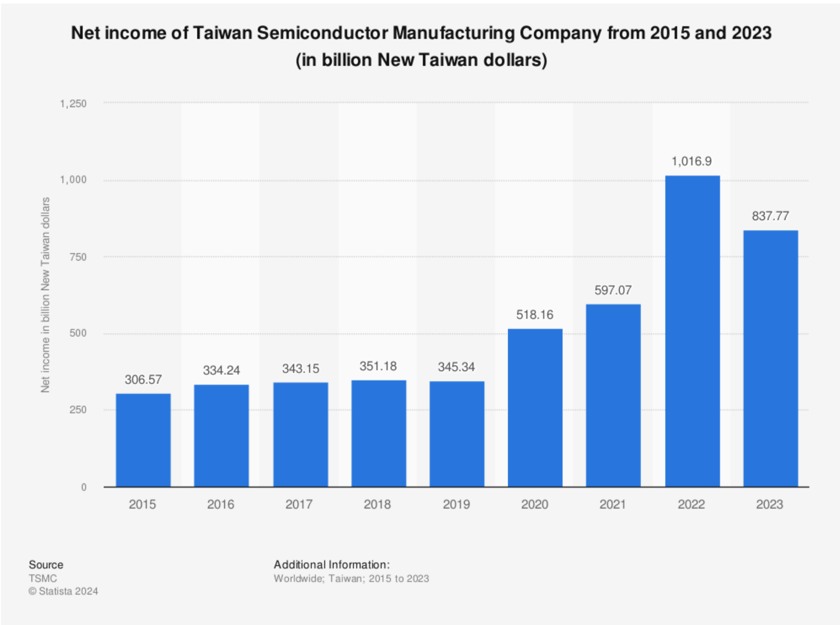

Figure 4.10: Net income of Taiwan Semiconductor Manufacturing Company from 2015 and 2023 (in billion New Taiwan dollars), TSMC (2024i)

TSMC's revenue history reveals a pattern of steady growth with periodic fluctuations. For the quarter ending March 31, 2024, revenue reached $18.846 billion, reflecting a 12.62% year-over-year increase (MacroTrends, 2024). However, the annual revenue for 2023 was $70.599 billion, marking a 4.17% decrease from the $73.67 billion recorded in 2022. The significant increase of 28.74% from 2021 to 2022 underscores a period of rapid expansion.

TSMC has demonstrated a significant investment in its capital expenditures, reflecting its commitment to maintaining and expanding its technological edge. In 2023, TSMC's CapEx totalled USD 30.45 billion (TSMC, 2024b). This investment funds new fabrication plants, upgrading existing facilities, and developing cutting-edge technologies. Quarterly breakdowns for 2023 show substantial and consistent investment throughout the year.

TSMC's operating expenses have also been upward, driven by the increasing costs associated with research and development, employee compensation, and operational overheads necessary to sustain its leading market position. For the fiscal year ending March 31, 2024, TSMC reported MacroTrends (2024):

- Quarterly OpEx for Q1 2024: USD 10.927 billion, a 19.73% increase year-over-year.
- Annual OpEx for 2023: USD 40.505 billion, marking an 8.94% increase from 2022.
- Annual OpEx for 2022: USD 37.182 billion, a 10.03% increase from 2021.
- Annual OpEx for 2021: USD 33.794 billion, a 22.85% increase from 2020.

The rising OpEx indicates TSMC's ongoing efforts to enhance its operational capabilities, including substantial investments in R&D to maintain its competitive edge and meet the demands of advanced technology nodes.

C-STOF dashboard of finance

The chart 4.11 provides a comparison of the financial data of Intel, AMD, and TSMC based on various key financial indicators: return on investment, revenue, EBIT, net profit margin, net income, and operating expenses. These financial trajectories exhibit the differences in their financial performance and strategic positioning. The following case study section will deeply focus on the competitive dynamics and key corporate strategic adaptations that led to these three companies' financial data variations.

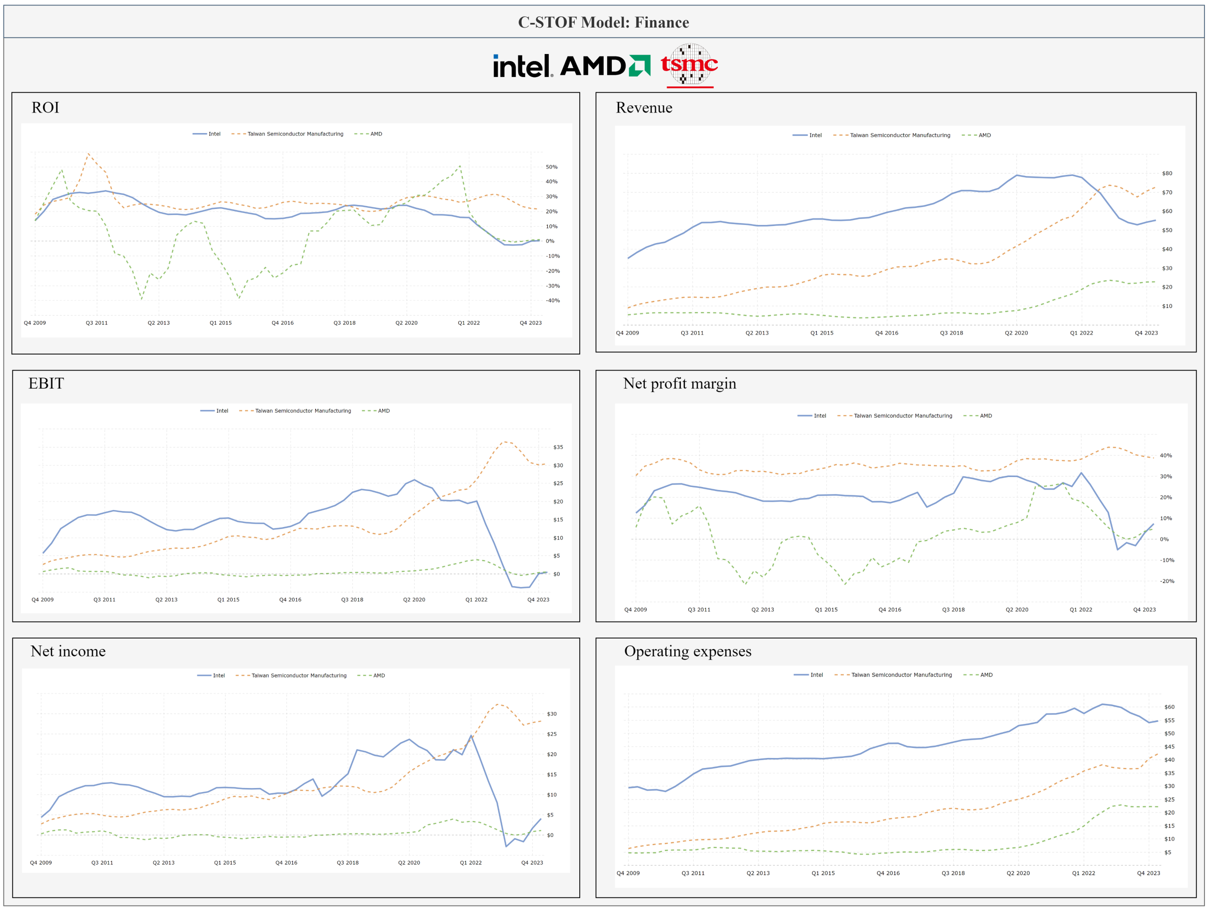

Figure 4.11: Comparison of financial metrics of Intel, AMD and TSMC from 2009 to 2023,
Data source: Intel ROI/Revenue/EBIT/Net Profit Margin/Net Income/Operating Expenses History from 2010-2023 | INTC, Macrotrends (2024b),
AMD ROI/Revenue/EBIT/Net Profit Margin/Net Income/Operating Expenses History from 2010-2023 | AMD, Macrotrends (2024a),
Taiwan Semiconductor Manufacturing ROI/Revenue/EBIT/Net Profit Margin/Net Income/Operating Expenses 2010-2024 | TSM, MacroTrends (2024)

4.3.6. C-STOF model summary

Based on the qualitative data gathered from the literature review, Intel, AMD, and TSMC are identified as illustrative examples of the IDM, fabless, and foundry business models, respectively. These three companies have exhibited significant interactions throughout the semiconductor industry's evolution, such as the early competition between Intel and AMD in the PC processor market, AMD's transition to a fabless model, and its following long-term strategic collaboration with TSMC. Consequently, these firms have been selected as subjects for detailed case studies.

In the preceding analysis using the C-STOF model, foundational insights were obtained into the three companies across five dimensions: customer value, service, technology, organization, and finance, and a brief comparison was visualized using the C-STOF dashboard. Intel, AMD, and TSMC exhibit certain commonalities despite their differing business models. All three emphasize high product and service quality in customer value and service to foster customer trust and establish long-term relationships. From a technological and product/service perspective, these companies prioritize innovation and efficiency as core values, reflecting the high technological and capital intensity of the semiconductor industry, which pushes rapid iteration and R&D innovation to maintain competitiveness. Additionally, given the broad and extensive nature of semiconductor products, these companies aim to diversify and expand their business domains to achieve higher market coverage and secure greater market share. Consistent with the descriptions and arguments by Barney (1991) and Teece et al. (1997), the C-STOF analysis reveals that these companies aspire to achieve VRIN qualities to gain sustainable competitive advantages and develop strong dynamic capabilities to cope with the rapidly evolving semiconductor industry. Furthermore, the extended semiconductor supply chain underscores the importance of maintaining long-term, stable relationships with upstream and downstream suppliers, which is particularly crucial for fabless companies like AMD that lack manufacturing capabilities.

The financial data presented for these companies expose the complicated interplay of various factors influencing their market performance. These factors extend beyond the internal aspects covered by the C-STOF model, including external elements such as market trends, supply and demand dynamics, and the emergence of discontinuous technologies. Given their fundamentally different business models, Intel, AMD, and TSMC exhibit distinct responses to competitive dynamics and strategic adaptations, resulting in distinct financial outcomes. For example, Intel's drastic revenue and net income decline since Q1 2022 contrast sharply with AMD's steady growth and relative stability. These introductory descriptions of corporate characteristics, related strategies, and market financial performance in the C-STOF analysis provide reference directions for case studies. Therefore, the subsequent case studies will examine the interrelationships and impacts of these companies' strategic adaptations in response to competitive dynamics throughout their development trajectories.

5
Case studies

This chapter adopts the Eisenhardt case study approach to conduct within-case and cross-case studies of three selected companies: Intel, AMD, and TSMC. These case studies focus on identifying significant strategic adaptations implemented by these firms in response to competitive dynamics over their developmental trajectories and assessing the subsequent impact on their market performance. This chapter aims to derive generalizable propositions that can be applied to the broader business context by examining these critical events. These propositions are listed at the end of the chapter.

5.1. Case study of intel

5.1.1. Intel introduction

Intel Corporation was co-founded by Robert Noyce, Gordon Moore (the originator of Moore's Law), and Andy Grove on July 18, 1968, under the name of "Integrated Electronics". According to data released by IC Insights (2021), Intel is the world's second-largest IDM semiconductor company, second only to Samsung Electronics. Intel is known for its innovation in microprocessor manufacturing and is the first company to launch the x86 architecture central processing unit (CPU), providing computing power for various devices, from personal computers to data centres.

Since its inception, Intel has operated as an IDM, covering the entire range of semiconductor production, including design, manufacturing, testing, and sales. Although Intel introduced the world's first commercial microprocessor chip in 1971, its primary business focused on Static Random-access Memory (SRAM) and Dynamic Random-access Memory (DRAM) chips until 1981. At that point, Intel significantly invested in new microprocessor designs and supported the burgeoning personal computer (PC) industry, making PC microprocessors its core business by the early 1990s. During this transformative period, Intel's partnership with Microsoft Windows was influential in shaping the PC landscape and consolidating its market position. However, by the early 2000s and into the late 2010s, Intel encountered increasing competition from fabless companies like AMD and NVIDIA, fellow IDM Samsung Electronics, and foundry TSMC (Tarasov, 2022). This heightened competition led to a notable decline in Intel's dominance and market share in the PC market. Nonetheless, as of 2023, Intel remains the leader in the x86 market with a 68.4% market share (Szewczyk, 2023). Adapting its corporate strategy is crucial for Intel to navigate the competitive dynamics within the capital and technology-intensive semiconductor industry across the company's development.

5.1.2. Intel's early competitive dynamics and strategic transformation

Formation, early Success, and strategic Shift

In August 1968, dissatisfied with Fairchild Semiconductor's equity incentive plan, Robert Noyce, the integrated circuit's father, Gordon Moore, and then-unknown development expert Andy Grove left Fairchild Semiconductor. With its founders being top-tier industry experts, Intel was securing substantial funding effortlessly. After its establishment, Intel, under Noyce's leadership, focused on semiconductor memory technology and became a leader in the semiconductor memory industry by the early 1970s. Meanwhile, Noyce and Moore set their sights on microprocessors, successfully launching the world's first commercial microprocessor, the Intel 4004, in 1971 (Faggin, 2015). Intel continued its momentum by developing the famous x86 architecture's predecessor, the Intel 8086, in 1978. Step by step, Intel established a pioneering advantage in microprocessor technology.

However, in the 1980s, Japanese manufacturers aggressively entered the DRAM market, causing Intel's DRAM market share to decline drastically from over 80% in 1974 to below 5% by 1984 (Burgelman, 1996; Kang, 2010). At this point, Intel's CEO, Gordon Moore, and Andy Grove decided to make a strategic shift, gradually abandoning the memory business to focus on the CPU. This bold decision solidified Intel's decades-long global dominance in the chip industry. A few years later, in 1987, Andy Grove, known for his stringent management style, took over as Intel's CEO. According to the data of Intel's annual revenue variation published by NasdaqGS (2024c), under his leadership, Intel transitioned from a memory chip manufacturer to the world's largest semiconductor company, with revenue soaring from $1.9 billion to $26 billion, an increase of over 1300%. During Grove's tenure from 1987 to 1998, Intel's stock price grew tremendously over 5000%.

Intel's shifting strategic pivot from DRAM to CPU development to counter Japanese competition to secure long-term market leadership exemplifies that

Proposition 10.1: IDMs' competitive pressure can be reduced by strategic reorientations, which is transferring the current focused business and product to another potentially promising field.

Competition with AMD and strategic formulation

In 1999, Intel faced another crisis, this time from domestic competitors targeting its CPU product line. AMD released the K7 architecture and the Athlon processor, outperforming Intel's Pentium core, making AMD's x86 chips the fastest in the world (Diefendorff, 1999). This propelled AMD into the limelight, directly challenging Intel and marking the beginning of AMD's rise. Intel watched its market share dwindle due to its inability to produce competitive products. Determined to rebound, Intel increased its research efforts to develop a new architecture to rival AMD's Ryzen CPUs. In 2001, under the leadership of Intel's fourth CEO, Craig Barrett, Pat Gelsinger was appointed as Intel's first CTO, tasked with developing key technologies such as Wifi, USB, Core, and Xeon.

Intel implemented the famous "Tick-Tock" strategy starting in 2005 to recover quickly. This strategy, formally proposed in 2007, was widely adopted by other semiconductor companies. It involved a two-year cycle, with process improvements (Tick) in the first year and architecture updates (Tock) in the second year, continuously alternating like a pendulum (C. Park, 2008), as shown in Figure 5.1.

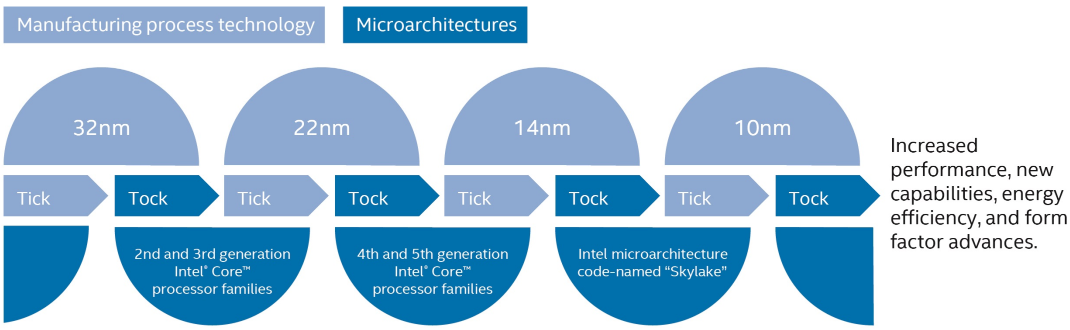

Figure 5.1: Intel "tick-tock" technology development cadence, Intel (2015)

Under Pat Gelsinger's leadership, Intel launched the Core 2 series CPUs in July 2006, outperforming AMD in both performance and power consumption. This advanced technology enabled Intel to make a strong comeback.

The implementation of the "Tick-Tock" strategy by Intel was a pivotal response to AMD's technological advancements, indicating that

Proposition 10.2: IDMs' systematic and structured strategies that are associated with taking innovation and production cycle factors into account are effective in maintaining the competitive edge due to the cyclical nature of the semiconductor industry.

Remarkable market performance and emerging challenges

During Paul Otellini's seven-year tenure as Intel's CEO, he focused on adjusting business and cost structures, promoting semiconductor innovation, diversifying investments, and injecting more commercial elements into Intel

(Hunger, 2020). During this period, data from NasdaqGS (2024c) shows that Intel’s total revenue grew from $38.826 billion in 2005 to $53.341 billion in 2012, and its net profit increased from $8.664 billion to $11.005 billion, solidifying its leadership in the semiconductor industry. Driven by strong business performance, Intel’s stock price also saw an upward trend during this period. Before the financial crisis, Intel’s stock price had rebounded more than 70% from its 2006 lows. After the crisis, Intel’s stock price surged, nearly doubling from 2009 to early 2012 (NasdaqGS, 2024b).

Despite the impressive revenue figures, a hidden crisis was brewing. Intel continued to rely on its existing technology base, with most revenue and profit coming from the PC processor business. Paul Otellini, the fifth of Intel’s CEOs from 2006 to 2013, attempted to explore new business areas, but this was largely unsuccessful, leading to a decline in stock price starting in mid-2012 (Sampath et al., 2015).

Intel’s experience under Paul Otellini reflects the balance between achieving revenue growth through business adjustments and the risks of technological enlargement, which indicates

Proposition 10.3: Significant revenue growth could be achieved for IDMs through business structure adjustments and diversification, yet the risk of technological stagnation could be highlighted if new market areas are not successfully developed.

5.1.3. Intel's recent strategic challenges and reorientation

The challenges of 14nm and strategic stagnation

During Brian Krzanich’s tenure as Intel’s sixth CEO, the company faced significant delays, taking three years to launch the 14nm process. This delay led to the failure of the well-known ”Tick-Tock” strategy (Joseph & Babu, 2024). Additionally, during this period, Intel did not achieve substantial breakthroughs in either the mobile chip or server chip businesses. Bob Swan, who succeeded Krzanich and served as CEO from 2018 to 2021, managed Intel’s finances efficiently, but his performance in driving technological advancement was lacking. By the end of Swan’s tenure, Intel’s CPUs were still utilizing the 14nm process, while TSMC had already advanced to the 7nm process. This stagnation allowed competitors to accelerate their research and development efforts, leaving Intel struggling to maintain its competitive edge.

The bottlenecks Intel encountered in developing processes smaller than 14nm demonstrate catastrophic outcomes, which implies

Proposition 10.4: Delays in technological advancements or stagnation in the technology-intensive semiconductor industry can undermine established strategic frameworks and result in losing competitive advantage and market leadership.

Strategic reorientation with IDM 2.0

In February 2021, Intel appointed Pat Gelsinger as the eighth CEO, succeeding Bob Swan. Under Gelsinger’s leadership, Intel introduced the IDM 2.0 strategy, which involved leveraging third-party chip foundries to enhance Intel’s manufacturing capabilities and establishing Intel Foundry Services to better integrate into the global chip supply chain (J. Li, 2023). Gelsinger also redefined future process node trajectory and accelerated process development. Additionally, he adopted a more open approach by considering x86 licensing to customers, aiming to build a collaborative ecosystem. These strategies acquired support from major semiconductor customers, including Amazon AWS and Qualcomm.

Gelsinger’s approach to capital allocation significantly differed from his predecessor’s. He increased investment in R&D, with recent results starting to manifest: the 10nm process technology progressed steadily, and the performance of the 12th generation Core processors showed significant improvements. Intel’s 2021 annual financial report highlights the initial success of Gelsinger’s efforts, with notable achievements including (Intel Corporation, 2021):

- The Data Center Group (DCG) reported revenues of $6.5 billion, a 10% year-over-year increase, marking a return to double-digit growth.
- The Internet of Things Group (IOTG) generated $1.37 billion in revenue, up 50% year-over-year, exceeding the expected $979.5 million.
- The Client Computing Group (CCG) reported revenues of $9.7 billion, a 2% year-over-year decline but slightly above the expected $9.64 billion.

The IDM 2.0 strategy, which integrates third-party foundries and emphasizes open ecosystem collaboration, aims to regain technological leadership and address previous innovation shortcomings, suggests

Proposition 10.5: IDM's strategic readjustment to include external collaboration, ecosystem building, and the spin-off of foundry services can help regain competitive advantage after stagnation.

Market reception and future outlook

The market remained sceptical despite Intel's positive performance in the third quarter. This scepticism could arise from doubts about Intel's ability to regain its former dominance or concerns over the substantial investments required for IDM 2.0 not yielding expected returns. Following the release of the financial report, Intel's stock price experienced a significant drop, declining over 9% in after-hours trading. Gelsinger recognizes that maintaining technological leadership is crucial in the rapidly evolving semiconductor industry. This understanding drives his commitment to the IDM 2.0 strategy, despite the associated financial risks and shareholder pressure due to short-term performance drops. His objective is to ensure that Intel retains its comprehensive capabilities in chip design and manufacturing, thereby securing its competitive position in the industry.

Technological breakthroughs require at least three to five years of significant investment, more like a high-stakes gamble. Despite the initial success of the IDM 2.0 strategy, Intel's market performance highlights the challenges of balancing long-term strategic investments with short-term financial market expectations, underscoring the difficulty of overcoming periods of stagnation. This indicates

Proposition 10.6: The semiconductor industry must rapidly advance product development and continuously make decisions and investments, betting on the next five to ten years. Strategies must carefully balance long-term strategic investments with short-term market performance.

5.2. Case study of AMD

5.2.1. AMD introduction

Advanced Micro Devices (AMD) was founded in 1969 by Jerry Sanders, a former Fairchild Semiconductor sales executive and a group of former Fairchild employees. As a fabless multinational company focused on the design of microprocessors and related technologies, AMD has grown into one of the leaders in the semiconductor industry, known for its innovative and high-performance computing products (Reed et al., 2022).

AMD initially focused on logic chips but soon turned to the microprocessor market. In the mid-1980s, a technology exchange agreement with Intel enabled AMD to produce and sell x86 microprocessors, establishing its market position. In 1999, AMD launched the Athlon processor, which outperformed Intel's Pentium III, and became a serious competitor in the high-performance microprocessor market. However, in the mid-2000s, AMD faced manufacturing problems and fierce competition from Intel. AMD spun off its manufacturing business to meet the challenges, renamed it GlobalFoundries, and officially transformed into a fabless company focused on microprocessor design.

In 2014, Dr. Lisa Su became CEO and led AMD to launch the Ryzen and Epyc processor series based on the Zen microarchitecture, which were widely praised for their high performance and efficiency (Naffziger et al., 2021). These products helped AMD regain market share and compete effectively with Intel in the consumer and enterprise markets. In the first quarter of 2017, AMD's global PC CPU market share reached 20.2% (PassMark Software, 2020). In March 2024, semiconductor stocks rallied, with AMD's valuation exceeding $300 billion for the first time in history (Grant, 2024).

5.2.2. AMD's early competitive landscape and strategic shifts as an IDM

Initial formation and early relationship with Intel

In its early years, AMD had a different trajectory compared to Intel. During the semiconductor startup boom of the 1970s, AMD struggled to secure investment. Interestingly, one of Intel's co-founders, Robert Noyce, was the first to invest in AMD's founder, Jerry Sanders. This initial investment created a close relationship between AMD and Intel. Three years after its establishment, in 1972, AMD went public. Initially, AMD positioned itself as a second supplier for Intel's products. This practice, common at the time, allowed AMD to gain a foothold by manufacturing and selling licensed versions of Intel's technology, which helped prevent monopolistic practices (Picker, 1999). Intel's X86 architecture became the industry standard for CPUs, leading to a prosperous period for both companies in the 1990s. By 2000, Intel's market value had reached $275 billion, making it the sixth largest company globally, while AMD's stock price increased fifteenfold over five years (NasdaqGS, 2024a, 2024b).

By the 1980s, as the personal computer market became saturated, both companies sought greater independence and market share. This led to increased competition, with AMD challenging Intel's dominance.

Independent development and the rise of the Athlon processor

The 1990s marked a transformative period for AMD as it aimed to lead in microprocessor technology independently of Intel. Significant investments in R&D and strategic acquisitions characterized this era, notably the acquisition of NexGen in 1995. Vinod Dham, NexGen's COO and a key former developer of Intel's Pentium processor, played a crucial role in enhancing AMD's technical capabilities. Under Dham's leadership, AMD launched its K-series architecture in 1996 and introduced the Athlon processor in 1999, based on the K7 architecture. This processor, the world's first to exceed a 1GHz clock frequency, directly competed with Intel's Pentium III, offering superior performance at a better price. The Athlon processor brought AMD a record net profit of $189.3 million, while its revenue also hit a record high of $1.09 billion (Hachman, 2000). Over the next few years, AMD introduced the first 64-bit x86 processor with the K8 architecture, and by 2006, its market share in the CPU market had reached 48.4%, nearly matching Intel's (PassMark Software, 2020).

Significant investments in acquiring technical expertise and developing proprietary architectures, exemplified by AMD's acquisition of NexGen and development of the Athlon processor, can rapidly elevate a company's market position and enable direct competition with industry leaders. Which indicates

Proposition 11.1: Targeted and large amounts of investments in R&D and strategic acquisitions for IDMs and fabless can significantly enhance competitive positioning through technological advancements and superior product offerings.

Expansion into the GPU market and subsequent challenges

By 2000, the CPU market was dominated by Intel and AMD, while Nvidia and ATI mainly led the GPU market after intense competition in the 1990s. AMD saw potential synergy in integrating CPU and GPU technologies and customer bases. In 2006, AMD acquired GPU manufacturer ATI for $5.4 billion, aiming to become a major player in both the CPU and GPU markets.

However, the acquisition led to significant challenges for AMD. In the two years following the acquisition, AMD wrote down $2.6 billion in goodwill, indicating that ATI's actual value was far less than the purchase price (Andreas, 2007). While the strategy of entering the GPU market was sound, the high acquisition cost severely strained AMD's cash flow. Meanwhile, Intel launched the Core 2 processors with a new microarchitecture, widening the gap with AMD. As mentioned, Intel also introduced the Tick-Tock strategy, alternating annual updates of process technology and processor architecture, advancing to a 14nm process, and regaining market dominance with its i3, i5, and i7 processors. During this period, AMD faced severe competition from Intel while grappling with the financial burden of the ATI acquisition. In 2009, its market share declined, and cash flow tightened, according to the data from Macrotrends (2024a), its debt accumulated to $5 billion. AMD was forced to compete in the CPU and GPU markets simultaneously, facing immense pressure in design and production.

5.2.3. AMD's Transformation and strategic revitalization

Transition to a fabless business model

In 2008, driven by the growing financial pressures and competitive challenges, AMD decided to divest its manufacturing operations to focus on chip design, officially transitioning to a fabless business model. This decision led to the creation of GlobalFoundries, an independent semiconductor foundry. The spin-off allowed AMD to offload its capital-intensive manufacturing assets, thereby freeing up resources for R&D and simplifying its operations. This strategic shift towards a fabless model aligned AMD with industry trends, enabling it to leverage the manufacturing capabilities of GlobalFoundries and TSMC later. This approach provided AMD with access to advanced manufacturing technologies without the substantial capital expenditure required to maintain its own fabs, setting the stage for future growth.

However, AMD struggled to achieve market success in the following years with its product launches. From 2010 onwards, its sales consistently declined. Data from PassMark Software (2020) shows that the company's CPU market share dropped from nearly 50% at its peak to just 20%, while its server CPU market share fell from 30% to a mere 1%. Consequently, AMD's market value descended to less than $2 billion, posing a significant challenge to its survival, let alone competing with Intel, whose market value was in the hundreds of billions.

AMD's divesting manufacturing operations to GlobalFoundries mitigates financial pressures and enhances strategic focus on R&D and design, which enables AMD to leverage external advanced manufacturing capabilities for competitive advantage. Which suggests

Proposition 11.2: Transitioning from an IDM to a fabless business model by divesting capital-intensive manufacturing business can enhance a company's operational agility, provide financial relief, and focus on innovation.

Lisa Su's tenure and strategic adaptations

In 2014, Lisa Su was appointed CEO of AMD, facing a severe situation. AMD was in a hazardous state, and Su implemented a series of measures, including streamlining processes, maintaining customer relationships, and cutting costs. Most importantly, she made two crucial strategic decisions in revitalizing AMD, as shown in Figure 5.2.

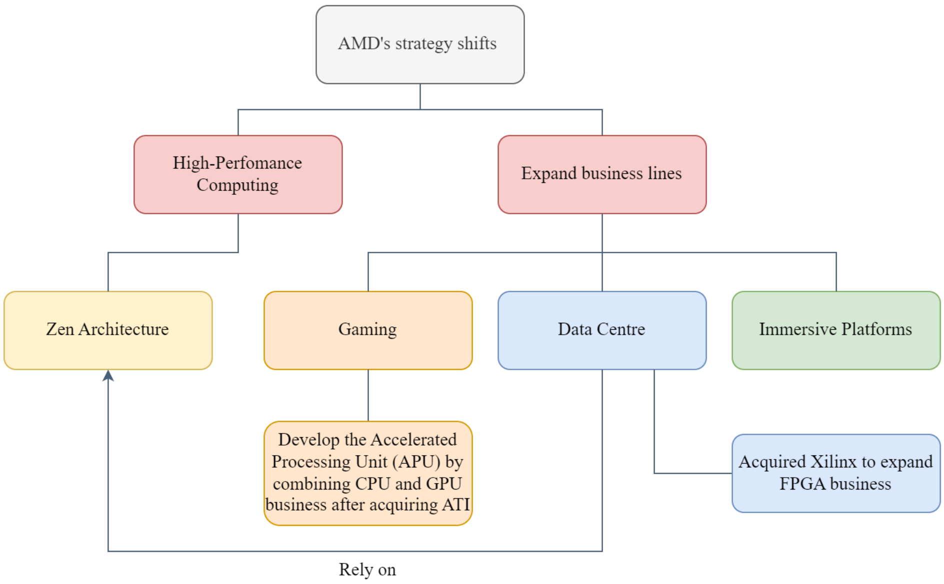

Figure 5.2: AMD's two major strategic changes after Lisa Su took over

The first strategic shift focused on high-performance computing. Previously, while AMD had shared the market with Intel, it had primarily targeted the mid-to-low-end segments. Su recognized that these segments offered limited prospects due to low added value and profit margins. She refocused AMD's efforts on developing high-performance chips. After two years of strategic adjustments, AMD launched the new Zen architecture-based Ryzen chips at the end of 2016. The Zen architecture represented an entirely new framework, distinct from Intel's process technology, utilizing Chiplet technology for higher flexibility and yield (Naffziger et al., 2021). The first generation of Ryzen chips delivered a 52% performance improvement, outperforming Intel's equivalent eight-core i7 6900K processor at less than half the price (Cutress, 2017). In the subsequent years, AMD continued to optimize the Zen architecture, launching the Zen 2 architecture with a 7nm process in 2019, which was applied to gaming consoles like the PS5, Xbox X, and S series, and the Steam Deck (Peddie, 2023). The Zen 3 architecture Ryzen 5000 series was released in 2020, followed by the Zen 4 architecture Ryzen 7000 series in 2022. The strong return of the Ryzen series enabled AMD to regain parity with Intel in the desktop CPU market.

Su's second strategic decision involved diversifying AMD's business lines. Historically, AMD had been overly reliant on CPUs. In 2015, she identified three key growth areas: gaming, data centres, and immersive platforms (Moorhead, 2016). Among these, data centres exhibited the fastest growth and the greatest potential. Data centres require high-end, energy-efficient chips, an area traditionally dominated by Intel. AMD needed to design top-tier chips, aligning with Su's first strategic shift towards high-performance computing to capture the data centre market. To further expand its business and technological capabilities, AMD acquired Xilinx for $35 billion in 2022. Xilinx is a leader in field-programmable gate arrays (FPGAs), which are widely used in devices such as electric vehicles, Mars rovers, and communication base stations (Wan et al., 2021). Through the acquisition of Xilinx, AMD aimed to broaden its business scope significantly. AMD has achieved substantial success by leveraging the high-performance Zen architecture and insights into data centre potential.

Under Lisa Su's leadership, AMD shifted focus from mid-to-low-end segments to high-performance computing, recognizing the former's limited prospects and low profit margins. This strategic pivot aimed to compete directly with Intel in the high-performance computing segment by developing advanced chip architectures like Zen. The strategy of expanding business lines she made identified three key growth areas—gaming, data centres, and immersive platforms to diversify AMD's business lines and reduce over-reliance on CPUs. The acquisition of Xilinx for $35 billion was a strategic move to expand AMD's technological capabilities. These indicate that:

Proposition 11.3: Strategic reorientation towards high-performance and high-margin segments is crucial for revitalizing a company's competitive edge in the technology-driven semiconductor industry.

Proposition 11.4: Diversification into multiple high-growth and technology-aligned business lines enhances a company's resilience and ability to capture emerging market opportunities.

5.3. Case study of TSMC

5.3.1. TSMC introduction

Taiwan Semiconductor Manufacturing Company (TSMC) was established in 1987 as the first dedicated semiconductor foundry in the world. Unlike IDMs like Intel, which both design and manufacture their own chips, TSMC specializes exclusively in manufacturing and offers extensive foundry services to both fabless companies and IDMs. Its client group includes global technology leaders such as Apple, Qualcomm, Nvidia, and AMD (Randy, 2013). This pure-play foundry model has revolutionized the semiconductor industry, propelling TSMC to become a critical player in the semiconductor supply chain.

By offering advanced process technologies and focusing on manufacturing excellence, TSMC consistently delivers high-quality, cutting-edge semiconductor solutions. TSMC was the first foundry to produce chips using 7nm, 5nm, and 3nm process technologies, setting industry standards (TSMC, 2024h). As of April 2021, its market capitalization exceeded $550 billion (TSMC, 2022). Compared to its $539 billion valuation in 2023, TSMC's market cap soared to $873 billion in 2024, achieving a 61.95% increase (NYSE, 2024).

5.3.2. TSMC's strategic positioning and relationships

Emphasis on customer value and non-competitive stance

As mentioned above about the customer value of TSMC, President Dr. C.C. Wei emphasized in 2024 that TSMC has always adhered to the principle of 'never competing with customers' to reflect TSMC's customer value proposition (Zhong, 2024). TSMC's wafer foundry clients are IC design companies. The collaborative model involves these design companies handing over detailed chip designs to the foundry, working closely together to verify performance and finalize manufacturing details. Therefore, besides possessing professional expertise, TSMC's principle of "not competing with customers" ensures alignment of interests with its clients. While IDMs like Samsung and Intel can also offer wafer foundry services to IC design companies, companies such as Apple, Qualcomm, and Nvidia are competitors to the IC design teams within these IDMs. In terms of customer trust, TSMC holds an unrivalled advantage over IDMs like Samsung and Intel, which is one of the key reasons for TSMC's success in the wafer foundry sector.

In 2015, Apple employed a "dual sourcing" strategy for its iPhone 6S A9 processor, splitting orders between Samsung's 14nm fab and TSMC's 16nm fab (Niu et al., 2019; R. Smith, 2015). By the time the A10 processor was introduced, Apple had selected TSMC as the exclusive supplier. TSMC's non-competitive stance and reliable technology mitigated concerns over potential technology leakage, solidifying TSMC's position as Apple's exclusive supplier for the A10 processor.

Close client collaboration and operational integration

TSMC maintains close interactions with its clients' senior management. According to TSMC's 2022 annual report, the top 10 clients contribute two-thirds of TSMC's revenue, and the top 20 clients contribute 80% (TSMC, 2023b). On the operational level, TSMC assigns dedicated teams to each customer to assist throughout the design, development, and production processes. For example, TSMC stationed a dedicated design and technology platform

(DTP) team at Apple for one to two years to expedite the integration of Apple's IC designs into TSMC's production system. This collaboration ensured a coherent transition of Apple's designs into TSMC's fabs, significantly enhancing power consumption, yield, and efficiency.

TSMC's commitment to not compete with its customers ensures it is seen as a trustworthy partner. This strategy makes TSMC the sole supplier of Apple's A10 processor, which suggests

Proposition 12.1: Unlike IDMs such as Samsung and Intel, foundries with non-competitive stances and relative technological advantages are more likely to become loyal and long-term partners for fabless companies, rather than choosing IDM's foundry services.

5.3.3. TSMC's technological leadership and competitive strategies

As highlighted in the TSMC (2023c)'s Sustainability report, TSMC has consistently maintained its technological leadership through sustained R&D expenditure above 8% of its net income, precise focus on R&D priorities, and an effective R&D model. Beyond these, TSMC's leadership can be attributed to four key strategies: independent innovation, solid technical accumulation, comprehensive process technology, and effective competitive strategies.

Independent innovation and correct technical pathways

Before the 0.13-micron technology node, TSMC and UMC dominated Taiwan's foundry market, with UMC's revenue once approaching TSMC's (Wade, 2000). The turning point arrived at the 0.13-micron node when IBM offered new technology to both companies. TSMC chose to develop its own copper process technology, while UMC chose to purchase IBM's technology for cooperative development. While strong in the laboratory, IBM's technology had low yields that were unsuitable for mass production. In 2003, TSMC's self-developed 0.13-micron process technology successfully debuted, significantly widening the gap between the two companies (TSMC, 2024h).

At the 28nm node, TSMC opted for the Gate-last process technology, while GlobalFoundries and Samsung chose Gate-first. TSMC's approach led to rapid yield improvements, whereas Samsung and GlobalFoundries struggled (LaPedus, 2011).

In advanced packaging, TSMC ventured into the field in 2011 with the 28nm node, recognizing that advanced processes were nearing physical limits and required substantial investments. Advanced packaging, however, remained cost-effective and could enhance chip performance economically. TSMC's integrated fan-out (InFO) wafer-level packaging was first applied to Apple's A10 processor, further establishing TSMC's lead over Samsung (Azémar, 2016). After more than a decade of deep cultivation, TSMC saw considerable revenue potential in the AI era, with its Chip-on-Wafer-on-Substrate (CoWoS) technology becoming the primary packaging technology for AI server chip manufacturers (Hu et al., 2023).

TSMC has consistently led technological innovation, starting with the 3.0-micron technology. By identifying the correct technical direction at critical nodes and committing to independent innovation, TSMC has achieved significant technological breakthroughs, which indicates

Proposition 12.2: Independent innovation and the selection of the correct technical pathways at critical junctures heavily influence companies' competitive advantage and technological leadership.

Steady technological iteration

TSMC's solid foundation in technology accumulation has allowed it to adhere closely to Moore's Law in its technological iterations. The company has successively launched processing technologies from 90nm to 3nm, and even currently 2nm nodes. This step-by-step experience, based on accumulated learning curves, provides TSMC with process and factory construction advantages that competitors find difficult to surpass, enabling TSMC to maintain long-term technological leadership.

Comprehensive technological variety

TSMC aligns its technology development with end-application needs, ensuring it captures and fully exploits market opportunities. In the smartphone sector, for instance, apart from the A11 processor manufactured by TSMC, various components of the iPhone X, such as the wireless charging IC, NFC chips, LTE transceiver chips, power management ICs, and wireless transceiver modules, were all produced by TSMC, even though designed by other companies like Qualcomm, Broadcom, Texas Instruments, and Intel (Yang et al., 2017). Consequently, TSMC emerged as a major winner when the iPhone X became a bestseller.

In the burgeoning Internet of Things (IoT) domain, TSMC replicated its smartphone technology layout experience. By forming elite teams from various departments, TSMC accelerated IoT technology development, particularly in specialized process technologies like radio frequency (RF) processes and embedded flash memory processes, ensuring comprehensive technical capabilities to meet diverse customer needs (TSMC, 2024f).

TSMC's strategy of aligning technology development with end-application needs to cater to specific market segments shows

Proposition 12.3: Seizing existing market opportunities to broaden business lines and identifying new market potential can help foundries gain market share.

Innovative competitive strategies

TSMC has implemented several innovative competitive strategies:

Leapfrogging in R&D:
While strictly following Moore's Law to introduce 90nm, 65nm, and 45nm technologies, TSMC skipped the 32nm node and introduced the 28nm node in 2010, reducing chip size by 20% and outperforming competitors' 32nm products in efficiency and cost (Edwards, 2012; TSMC, 2024h). This move caught competitors like Samsung, IBM, and GlobalFoundries off guard, making 28nm the most profitable and longest-dominating technology node in TSMC's history.

'Nighthawk Force' Project for Accelerated R&D:
In 2014, TSMC launched the "Nighthawk Program," organizing a team of over 300 R&D engineers from its 40,000 employees to work night shifts, achieving 24/7 continuous R&D (V. Chen, 2021). This program, with 1.5 to 2 times the usual investment in workforce and time, successfully developed the 10nm node by the end of 2016. The team then worked on 7nm and 5nm nodes, transforming into a permanent system.

Parallel R&D:
To accelerate development amidst Samsung's aggressive advancements, TSMC changed its sequential R&D model to parallel, developing 10nm and 7nm processes simultaneously rather than waiting for one to complete before starting the next. This reduced the cycle time from 16nm to 10nm to nearly two years and from 10nm to 7nm to five quarters, as shown in Figure 5.3.

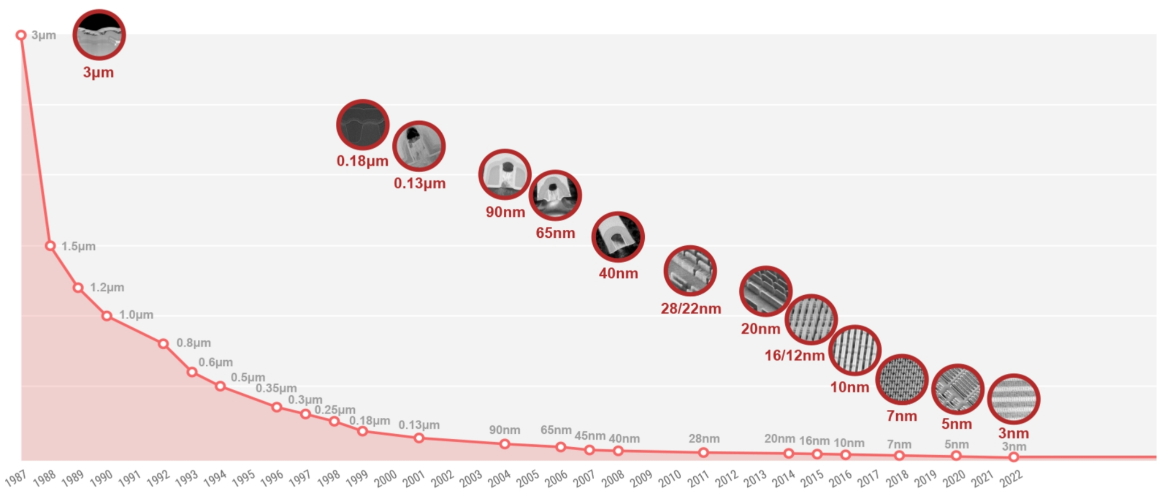

Figure 5.3: TSMC process technology evolution, TSMC (2024h)

The implementation of leapfrogging technology nodes, accelerated development programs, and parallel process advancements significantly enhances the competitive edge of TSMC in the industry, which indicates

Proposition 12.4: In the rapidly iterating and highly competitive semiconductor industry, only those with the fastest R&D speed, the highest R&D efficiency, and the most advanced and mature process technology can gain market leadership and set market trends.

5.4. Cross-case studies

5.4.1. Competitive edge loss caused by underdeveloped process technology

Intel once dominated the PC and server markets with its X86 architecture, leveraging its IDM model, which involved in-house design and production, to surpass competitors in process technology. This advantage persisted through the 1990s, with only AMD's Athlon series briefly challenging Intel's Pentium series. Intel's Pentium and server chips, like Xeon, faced little competition for the most part. However, the landscape shifted dramatically in 2007 with the introduction of Apple's iPhone, which marked the beginning of the smartphone era. Intel failed to enter this burgeoning mobile market successfully. It wasn't until 2012 that Intel launched the ATOM chip specifically designed for phones, but by then, it was too late; ARM architecture had already become the standard (B. Smith, 2008). This failure indicated that Intel did not succeed in the design competition to become the dominant design during the era of ferment. In 2013, Intel's mobile device chip division lost $3.1 billion, and in 2014, the losses escalated to $4.2 billion, accounting for one-tenth of its total revenue (Eassa, 2015; Hollister, 2014). By 2016, Intel announced the termination of all mobile device chip projects, withdrawing from the market in defeat.

A deeper issue during this period was Intel's slow progress in chip manufacturing processes. The 10nm process, originally slated for mass production in 2015, faced multiple delays and only went into production in 2019 (Shilov, 2018). These deferrals resulted in the passive extension of the life of the 14nm process, and the chips released during this period did not meet performance expectations, allowing AMD to catch up. By then, AMD had transformed into a fabless chip design company, utilizing TSMC's 7nm and 5nm process technologies to launch high-performance Zen architecture chips, catching Intel off guard. When Intel finally mass-produced 7nm chips, TSMC was already producing 3nm chips, and AMD's fifth-generation Zen architecture was set to use TSMC's 4nm process (MacDiarmid & Bhaskaran, 2024b). Intel's lagging process technology provided competitors with greater market opportunities.

Although Intel remains the leader in the X86 architecture server chip domain, its market share is being eroded by AMD's EPYC processors. As for Intel's AI chips, the company entered the field later than Nvidia and AMD. In 2019, Intel acquired AI chip company Habana Labs to break into the AI chip market. Given its late entry, Intel continues to use the older HBM2E technology, and its chip interconnect technology lags behind Nvidia (Kennedy, 2024). It appears that Intel will have significant challenges in posing a real threat to Nvidia, especially with AMD also in the mix.

Proposition 13.1: Market leadership in specific segments can be eroded by competitors leveraging advanced foundry process capabilities.

Proposition 13.2: Inadequate participation in emerging markets can lead to significant financial losses and market share declines for IDM companies with relatively low flexibility.

5.4.2. Strategic reform and revitalization: from the perspective of Intel's IDM 2.0

After Pat Gelsinger returned to Intel as CEO, he initiated comprehensive reforms to revitalise the company. Gelsinger introduced the IDM 2.0 strategy, focusing initially on chip production. Recognizing that it was impossible to prevent other tech companies from developing custom chips, he leveraged Intel's extensive manufacturing experience as an IDM to assist these companies in chip production. Gelsinger established the Intel Foundry Services (IFS) sector and separated it from other business units to enhance transparency and attract customers (Intel Corporation, 2021). To gain an edge over other foundries like TSMC and GlobalFoundries, Gelsinger focused on addressing process and yield issues, which were critical for both the foundry business and Intel's own chip upgrade plans (McGregor, 2024).

Gelsinger's efforts included the construction of new factories, such as new plant expansion in Europe and Fab 52 and Fab 62 in Arizona (Intel, 2022a, 2024d). Originally, Fab 52 was scheduled to begin operations in 2024 to produce 20A (2nm) process chips, but mass production was delayed until the second quarter of 2025. Similarly, Fab 62, slated to produce 20A chips, experienced some delays (Liang, 2024). Gelsinger has an ambitious plan to achieve five process nodes in four years, aiming to surpass the 2nm process by the second quarter of 2025, although the timeline appears challenging.

Beyond production, according to the interview done by O'Donnell (2024) in the event of IFS Direct Connect, Gelsinger has worked to improve Intel's design capabilities, enhancing packaging technology and fully adopting Chiplet small chip packaging technology. Intel has also increased its investment in the discrete graphics card and AI accelerator markets. Although the ARC series graphics cards were developed before Gelsinger's tenure, they were not a priority. Now, the ARC series has received more resources with the goal of challenging the dominance of Nvidia and AMD in the graphics card market.

During his tenure as CEO, Gelsinger has made significant efforts to address Intel's weaknesses and strengthen overall planning. However, Intel's late start and missed opportunities in several key areas mean the company needs time and investments to turn its fortunes around. The pressing issue of process technology remains critical; without resolving this, Intel will struggle to catch up with TSMC and face even greater challenges.

Proposition 13.3: Leveraging IDM experience to spin off and build fab to compete in foundry services could enhance the market position.

Proposition 13.4: Achieving advanced process technology and addressing yield issues are crucial for IDM competitiveness in foundry markets.

5.4.3. TSMC and Intel: Competitive dynamics and strategic paths in advanced semiconductor technology

TSMC's technological challenges against IDMs

At the end of 2022, TSMC announced the mass production of 3nm process chips; and planned to commence 2nm chip production in 2025 at the 2024 North American Technology Symposium (Shilov, 2024; TSMC, 2024h). The only competitors capable of challenging TSMC's advanced process technology are Samsung and Intel, which aspires to transition into a chip manufacturer. However, the third sub-figure in Figure 4.4 shows that in 2023 Q1, neither company can yet threaten TSMC's 60.3% market share; Samsung, ranked second, holds only a 9.9% market share, with other smaller companies dividing the remaining market share, thus consolidating TSMC's dominant position.

Nonetheless, TSMC must still confront the challenges posed by the diminishing returns of Moore's Law, which complicates transistor miniaturization. This has led to the development of gate-all-around (GAA) technology, offering technical feasibility for process breakthroughs. However, chip manufacturers must balance innovation with cost-effectiveness as process complexity and costs surge. Consequently, advanced packaging technology has become another core competitive edge for foundries. Unfortunately, TSMC's two main rivals, Samsung and Intel, possess both of these crucial technological pathways.

Intel and TSMC's strategic competition

Intel's disadvantage in chip manufacturing compared to TSMC has delayed its production of 7nm and even 5nm chips, resulting in products that lag in performance and efficiency. Intel's attempts to procure EUV lithography machines were hindered by ASML's limited production capacity and TSMC's priority in receiving shipments (van Gerven, 2024). In 2024, Intel successfully introduced the first high numerical aperture (0.55 NA) EUV lithography machine from ASML, planning to deploy it for nodes beyond the Intel 18A process technology within the next two to three years (Intel, 2024h). Meanwhile, TSMC adopted a more cautious strategy, favouring cost-effective mature technologies to ensure market competitiveness. Intel's bid to achieve a leapfrog advancement with high NA EUV technology parallels Samsung's 2017 strategy of early EUV adoption to surpass TSMC's 7nm process.

Currently, Intel's strategy appears prudent, as it focuses on high NA EUV technology necessary for the 2nm node while placing substantial orders with TSMC for advanced processes like 3nm, positioning itself for both offensive and defensive stances. Achieving a first-mover advantage in 2nm technology not only aims to secure a lead in latecomer advantage but also determines the trajectory of its future foundry business. The successful mass production of 2nm technology is crucial for Intel's future development and its bid to challenge TSMC. If Intel can achieve an early lead in the 2nm node and improve yield rates faster than TSMC, it could become the first company to adopt high NA EUV for large-scale production. This would likely attract customer orders, thereby facilitating its IDM 2.0 strategy and potentially surpassing Samsung in the foundry market.

However, Intel still faces significant challenges. While leading-edge processes are essential, customer support is equally vital in the foundry industry. Competing with industry giants like TSMC, which has a longstanding stable customer base and core values, Intel must focus on acquiring new customers, maintaining long-term loyalty, and reliably producing customer chips. To truly catch up and surpass TSMC, Intel will need to invest considerable effort and time.

Proposition 13.5: For IDMs and foundries, which have manufacturing capabilities, first-mover advantage in next-generation process nodes can define competitive trajectories in the foundry market.

Proposition 13.6: For IDMs and foundries, it is necessary to balance innovation and cost-effectiveness when developing advanced process technologies to maintain a competitive edge.

5.5. Proposition summary from case studies

Upon reviewing all the case studies and cross-case studies for Intel, AMD, and TSMC, a total of 18 propositions were obtained. As shown in the following Table 5.1.

Table 5.1: Propositions derived from case studies

Within-case studies	**Propositions**
Intel case	10.1, 10.2, 10.3, 10.4, 10.5, 10.6
AMD case	11.1, 11.2, 11.3, 11.4
TSMC case	12.1, 12.2, 12.3, 12.4
Cross-case studies	**Propositions**
	13.1, 13.2, 13.3, 13.4

The propositions were then refined and categorized into two major categories: Competitive dynamics & technological advancement and Strategic reorientation & diversification, with those redundant, generalizable, and non-specific propositions subsequently deleted, merged, and modified. The refined proposition list consists of 9 propositions are shown in the Table 5.2.

Table 5.2: Categorized and modified propositions from case studies

Categorization	**Propositions**	
Competitive dynamics & technological advancement	**14.1** *(10.1, 11.3, 11.4, 12.3, 13.1)*	IDMs, fabless, and foundries' competitive pressure can be reduced, their competitive edge can be revitalized, and the company's resilience can be enhanced by strategic reorientations, which transfer the R&D and investment from the current focal business and product to another potentially promising field, broaden and diversify business lines towards high-performance and high-margin segments or niche markets.
	14.2 *(12.4, 13.4, 13.5, 13.6)*	Achieving advanced next-generation process node technology rapidly through high R&D expenses and efficiency to possess first-mover advantages while balancing innovation and cost-effectiveness when developing it and addressing yield issues is crucial for IDM and foundries to gain market leadership and define future competitive trajectories.
	14.3 *(12.1)*	Unlike IDMs, foundries with non-competitive stances and relative technological advantages are more likely to become loyal and long-term partners for fabless companies rather than choosing IDM's foundry services.
	14.4 *(10.2, 10.4)*	Due to the cyclical and technological-intensive nature of the semiconductor industry, IDMs' systematic and structured strategies that are associated with taking innovation and production cycle factors into account effectively maintain the competitive edge, while the strategic frameworks could be undermined by delays or stagnation of technological advancements.

Categorization	Propositions	
	14.5 *(13.2)*	Inadequate participation in emerging markets can lead to significant financial losses and market share declines for IDM companies with relatively low flexibility.
Strategic reorientation & diversification	**15.1** *(10.3, 10.6, 12.2)*	The semiconductor companies, whether IDM, fabless or foundry, must precisely predict the correct technical pathways at critical junctures to avoid undeveloped markets causing technological stagnation, rapidly and independently advance product and process development and innovation, continuously update strategies according to the market, and invest from the vision of the next five to ten years. Strategies must carefully balance long-term strategic investments with short-term market performance.
	15.2 *(10.5, 11.2)*	IDM's strategic readjustment to include external collaboration, ecosystem building, and the spin-off or the divesting of foundry services to transit to fabless or separately operating the design and manufacturing sector can enhance operational agility, providing financial relief and focus on innovation, thereby regaining competitive advantage after stagnation.
	15.3 *(11.1)*	Considerable investments in R&D and targeted strategic acquisitions of companies with complementary and advanced technologies for IDMs and fabless can significantly enhance competitive positioning through technological advancements and superior product offerings.
	15.4 *(13.3)*	IDM can leverage its experience in manufacturing to build new fabs to compete in foundry services with other foundries.

The italic numbers in brackets at the proposition number represent the original proposition number or the original propositions that were merged or modified. For example, 14.1 *(10.1, 11.3, 11.4, 12.3, 13.1)* means the proposition 14.1 is derived based on the combination and modification of original propositions 10.1, 11.3, 11.4, 12.3 and 13.1.

6

Interview data analysis

6.1. Interview overview

The interview methodology for this study was developed to gather in-depth insights from industry experts regarding the competitive dynamics, strategic adaptations, and market performance of different business models within the semiconductor industry. Semi-structured interviews were chosen due to their flexibility, allowing for the exploration of specific topics while accommodating new, relevant issues raised by interviewees.

The interviewees were selected based on the interview criteria Table 2.2, and interviews are conducted strictly following the interview protocol denoted in the section 2.1.4. The following table 6.1 shows the details of each interview conducted.

Table 6.1: Interview details

Interviewee code	Interview date	Interview form	Duration	Company type	Role
I1	17/6/2024	Microsoft Teams online meeting	39 minutes	IDM	Heads of Strategy
I2	23/6/2024	Microsoft Teams online meeting	56 minutes	Fabless	Corporate Cooperation Coordinator
I3	29/6/2024	Microsoft Teams online meeting	50 minutes	Fabless	Vice President
I4	4/7/2024	Microsoft Teams online meeting	85 minutes	Foundry	Back-end Supply Chain Manager
I5	4/7/2024	Microsoft Teams online meeting	39 minutes	IDM	Business Group Chief
I6	6/7/2024	Microsoft Teams online meeting	44 minutes	Foundry	General Manager of R&D Center

A total of six interviewees from semiconductor IDM, fabless, and foundry companies were interviewed, with each interview lasting an average of 52 minutes. The interview sequence was not continuously arranged according to the type of business model. This approach was intentional because of the speciality of the research topic: the interactions between different semiconductor business models are multiple and repeated, including aspects of competition and cooperation, etc. The semi-structured interview method allowed insights from each interview from one business model to inform and enrich subsequent interviews with participants from different business models. Consequently, this approach enhanced the depth and diversity of the interview questions, thereby increasing the overall quality of the interviews.

6.2. Coding process

Each interview was recorded and transcribed using the transcription function in Microsoft Teams. The transcripts were subsequently reviewed and corrected against the recordings to accurately capture terminologies and key points in the experts' responses. Following this, the qualitative data analysis software ATLAS.ti was employed to process the interview data. A coding scheme was developed based on the research questions and interview content. This scheme comprised primary themes, codes, and sub-codes. The primary themes included business model, business model interaction, competition-related aspect, strategy-related aspect, market-related aspect, and industry-related aspect, as detailed in the table 6.2 below.

Table 6.2: Code scheme for interview data

Themes	Code	Sub-code
Business Models	IDM, Fabless, Foundry	Features, Advantages, Disadvantages/challenges, Differences, Focuses, Relationships
Business models interaction	IDM and fabless, IDM and foundry, Fabless and foundry	Collaborations, Competitions, Transformations
Competition-related	Competitive dynamics, IDM/Fabless/Foundry competitive pressure, Technological advancement	Influence on strategic adaptations, Competitive advantages, R&D
Strategy-related	IDM/Fabless/Foundry Strategic adaptations, Strategic visions, Operations	Strategic responses to competition, Proactive strategies, Reactive strategies, Long-term strategies, Short-term strategies, Strategic reorientation
Market-related	Market performance, Market trends, Market demands	IDM/Fabless/Foundry market performance metrics, Explicit indicators, Implicit indicators, Future market, Market penetration, Market coverage, Niche market, Diversifying
Industry-related	Industry features, Industry nature	Capital-intensive, technology-intensive, Cyclicality, Volatility

In the following interview thematic analysis, the brackets at the end of the sentence represent references to the interview content, where the first number in the brackets represents the code of the interviewee, and the second number represents the code generated by ATLAS.ti for the interview content excerpts. For instance, the notation (1:15) at the end of the sentence signifies that the quoted excerpt originates from interviewee 1. The number 15 represents the specific coding identifier assigned by ATLAS.ti, indicating that this is the 15th coded segment within the interview transcript. The brackets after the proposition indicate this proposition is extended and modified from the previous proposition, and the numbers in the brackets imply the original proposition number, for example, Proposition 16.2 *(1.2)*.

6.3. Thematic analysis of interviews

6.3.1. Business models in the semiconductor industry

Features of semiconductor industry, IDM, fabless, and foundry model

The semiconductor industry is cyclical. Extending Anderson and Tushman's Cyclical Model of Technological Change from a macroeconomic perspective, the cyclicality of the semiconductor industry manifests in upward and downward phases. A core factor driving the industry's upturns and downturns is the supply-demand relationship in the market (1:15). During an upturn, intense competition in the market stems from strong demand from end customers. At this time, the pressure is more concentrated on the production and manufacturing end of the industry ecosystem, which needs to coordinate rising upstream supply chain costs while ensuring its production capacity and inventory. In a downturn, due to weakened demand, the pressure shifts to the sales end, which needs to maintain market share by continuously lowering prices and controlling upstream costs while planning production capacity and ensuring stable profits (1:16). The cyclical nature of the capital- and technology-intensive semiconductor industry is characterised by long R&D cycles and extended validation periods, which can span several years, especially in sectors that demand high reliability, such as automotive and data centres (2:9). This cycle varies across different market segments. For instance, logic IC semiconductors, exemplified by advanced processes, have an iteration cycle of about one to two years. In contrast, power semiconductors, which are less radical in their iteration, may require three to five years to update a generation (5:8). These two types of semiconductors will be briefly introduced later. Additionally, the semiconductor industry is volatile, with factors such as wars, pandemics, and consumption downgrades causing major market disruptions and driving the industry into upward or downward phases (4:20). The cyclical nature, volatility, and capital- and technology-intensive features of the semiconductor industry are depicted in Figure 6.1.

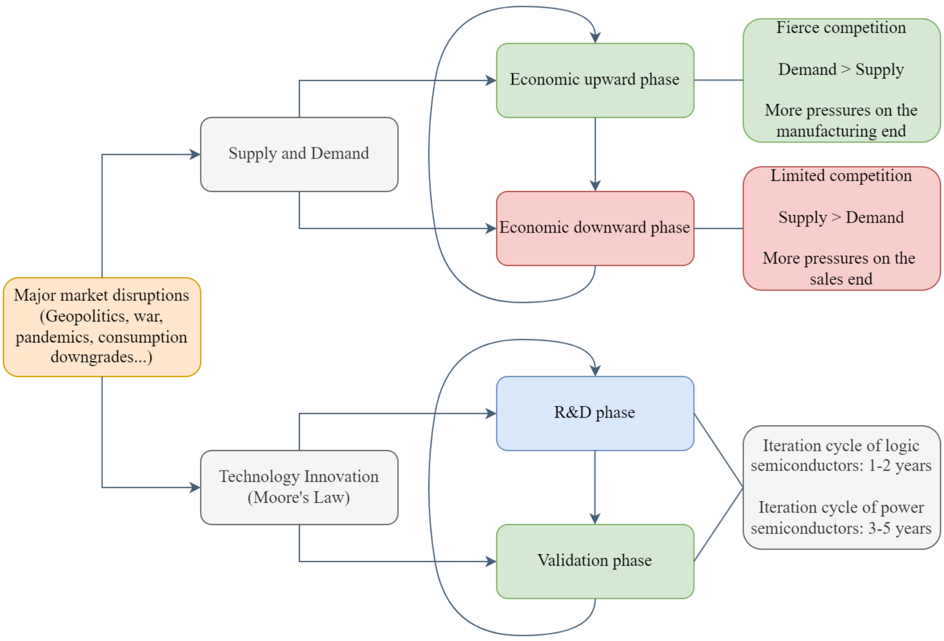

Figure 6.1: The cyclical, volatile, technology and capital-intensive nature of the semiconductor industry

In the early stages, when semiconductor process nodes were relatively elementary, the design of corresponding semiconductor devices was simpler, allowing mature processes of the time to manufacture and implement these designs. However, as predicted by Moore's Law, the increasing number of transistors per unit area and the rapid growth in demands for transistor density and performance have created a mismatch between design and process. Suppose a design company needs to wait for a fab to develop a new process or use outdated processes to match its design. In that case, it will lead to reduced product performance and delayed product launch, further impacting the product's competitiveness. The issue of matching design and process has fostered the emergence of the IDM model, as having control over process technology allows for the modification and optimisation of chip design while simultaneously advancing process technology to achieve technological leadership in products. The value of the IDM model is not primarily derived from its design but from the stable and reliable production it provides

(4:3). As represented by TSMC's early introduction of the Design-technology Co-optimization (DTCO) concept, it emphasises the need for open collaboration between process R&D and design R&D departments to explore possibilities in design innovation and process capabilities (Yuan, 2022). Today, the boundaries between the so-called IDM and Fabless-foundry models are not as rigid (3:9). The general association between fabless and foundry, broadly speaking, can also be considered a form of IDM. Although design and manufacturing are separate, their relationship has reached an IDM level. In a narrow sense, IDM refers to semiconductor companies like Samsung and Intel (4:30).

Proposition 16.1: For IDM and fabless-foundry models, the degree of matching between design and process and implementing design technology co-optimization will affect product performance and time to market, thus affecting product competitiveness.

The semiconductor industry encompasses various product segments, each with distinct business formats (1:12). Two critical branches are power and logic IC semiconductors. Power semiconductors, represented by companies like Infineon, are a specialised area within discrete devices. These semiconductors are used for controlling and converting electrical energy, primarily in power electronics applications such as power conversion, motor drives, and lighting control. Logic IC semiconductors, on the other hand, include IC composed of numerous transistors, capacitors, resistors, and other components, with companies like Broadcom and Intel being key representatives. Logic ICs are widely used in digital electronics, such as computers, smartphones, and tablets. Companies' business models tend to lean towards the IDM model in this specialised process domain. The rationale is that the design of power semiconductors is relatively simple compared to logic semiconductors. Still, it is crucially dependent on the reliability and stability of the manufacturing process (4:5, 5:8). Customers emphasise the need for a stable production line for power semiconductors, as different production lines can result in performance inconsistencies, resulting in re-validation of products. The inconvenience facilitates power semiconductor companies to adopt the IDM model by owning their fabs. Fortunately, power semiconductors do not require the cutting-edge process technology associated with logic semiconductors, making the cost of establishing fabs relatively lower (5:17).

Proposition 16.2 ***(1.2)*****:** Within the same semiconductor business sector, the relationships between fabless companies and foundries are characterized by a non-competitive, complementary, and mutually beneficial collaboration, while the relationship between fabless companies and IDM is competitive regarding market share and technological advancement.

Unlike IDM, the value in the fabless model stems from chip design. This IP-intensive business model creates significant value in the semiconductor industry, with IP protection forming the foundation of cooperation between fabless companies and their customers (5:1, 6:1). For fabless companies designing logic IC semiconductors, such as microprocessors, microcontrollers, and digital signal processors, the cost of outsourcing production is significantly lower than the cost of design. In this model, the collaboration between fabless companies, who handle design, and foundries, who handle production, is logical and cost-effective (5:2). Conversely, for power semiconductors, the production process holds more importance than the design process. Hence, more stable production and superior process capabilities enable chips to achieve higher voltage and current per unit area, making IDM a better model for this segment. The synchronous update and collaboration of design and process technology in IDM naturally lead to improved performance and efficiency.

Proposition 16.3 ***(3.1)*****:** Fabless companies in the logic semiconductor field are more dependent on core IP and advanced EDA tools than IDMs, while fabless companies in the power semiconductor field emphasise stable outsourcing production due to the distinct technical features, architectures and focus.

The rise and success of the foundry model, driven by Moore's Law and the growth of the semiconductor industry, can be attributed to product-driven markets, cost-driven industry trends, and technology-driven process advancements (4:1, 4:7, 4:10). For logic IC semiconductors, the recent development of the foundry model is primarily due to the widespread adoption of consumer electronics and the rise of electric vehicles, increasing the demand for automotive-grade chips. Essentially, becoming an IDM involves a fabless company acquiring factories and process capabilities, which incurs costs far higher than design costs, which are not at the same level. Operating a fab requires robust capital capabilities and internal funding sources, with only successful product sales providing the necessary funds to support process advancements (4:1). Additionally, fab operations rely heavily on orders, with equipment depreciating when not in use. Continuous operation or achieving a certain utilisation rate is essential for a fab to break even or remain profitable (4:11). Capacity planning is the primary consideration in the foundry model, facilitated by the complexity of semiconductor processes, which can involve hundreds or even thousands of steps (4:10). After completing one process step, production lines and equipment become available for other products, allowing more capacity to be efficiently utilised.

Proposition 16.4: The heavy reliance on orders drives foundries and IDMs with foundry service to make detailed plans for existing and future production capacity to achieve break-even or maintain profitability.

Advantages, disadvantages of IDM, fabless and foundry model

The primary advantage of the IDM model is its comprehensive coverage of the semiconductor industry's front-end ecosystem. IDM creates significant synergies by retaining all core competencies internally, from design through manufacturing to packaging and testing. Drawing from the Resource-Based View, this model facilitates more efficient resource integration, enabling rapid responses to customer demands, enhanced production efficiency, and cost reductions (1:1, 1:23, 6:8). IDM's extensive customer base is a notable advantage. Its holistic industry coverage allows IDM to offer integrated solutions, particularly beneficial for small and medium-sized customers lacking in-house solutions development teams (3:17). When IDM introduces new products or application scenarios; they can leverage their existing customer relationships. Long-term customers face high switching costs and may continue to support IDM products despite suboptimal performance in low-end or mid-range applications due to user habit (2:5). Additionally, IDM can strategically outsource many mature, low-margin products while retaining core business internally, thus optimizing design and manufacturing processes to gain performance and pricing advantages (1:27, 3:3).

Proposition 17.1 ***(4.1, 6.2)*****:** By internally covering all core steps of developing a semiconductor product, the vertical integration IDM model enables deeper penetration to end-markets and supply chain participants and continuously providing holistic and reliable solutions for long-term customers who are seeking a single-source solution due to the high switching costs accumulated by user habit.

However, the IDM model's heavy asset nature presents significant disadvantages, particularly obvious during expansion phases requiring substantial upfront investments. The initial return on investment can be minimal, potentially requiring up to a decade to break even (1:2). The essential issue lies in the interplay between cost control and investment cycles; misalignment in timing can disrupt market rhythms. Prematurely investing may result in insufficient order volumes to sustain wafer fab operations, leading to low capacity utilization and significant financial losses. Conversely, delayed investment may result in missed market opportunities, where supply is far lower than demand, driving up costs and prices. Due to the industry's cyclical nature, IDM faces great challenges in maintaining investment flexibility, as market fluctuations are inherently unpredictable (5:4). Predicting market share poses additional challenges; overestimating demand without adequate technical foundations can overextend the business, making it difficult to support fab operations (3:25). In such scenarios, if the IDM possesses a strong design business, a viable strategy might be to divest the fab, as illustrated by AMD's strategic decision discussed in the section 5.2.3. Nevertheless, once an IDM recoups its fab investment, its production efficiency will improve, and associated costs will decrease.

Proposition 17.2 ***(8.1, 8.2)*****:** The heavy asset nature of IDMs indicates the high fixed and variable costs, which poses the significance of investment flexibility that balances the cost control and investment cycles to keep pace with market rhythms, yet the fabless-foundry collaboration model shows a more flexible and cost-effective approach.

In contrast to the IDM model, the fabless model is distinguished by its light asset nature, eliminating the need for significant investments in fixed assets and resulting in lower asset burdens and higher operational flexibility (3:1). When fabless companies form partnerships with suitable foundries and assembly facilities; their financial returns can be favourable. During market downturns, these companies can relieve financial pressures by reducing the number of orders (1:3, 3:1). The inherent flexibility of fabless firms enables them to explore and penetrate competitive niche markets, thereby avoiding intense competition, only under the preconditions of received support from foundries, customers, and the supply chain (3:16), which strengthen the confirmation of Proposition 14.1.

The fabless model has its disadvantages, primarily arising from the lack of control over the entire production process. In scenarios of market shortages, the cost of outsourcing production to foundries can increase dramatically, and fabless companies face the dual challenge of managing costs while securing sufficient production capacity (1:4). Especially in situations with insufficient order volumes and limited market capacity, many fabless companies compete for foundry capacities, highlighting the importance of stable partnerships with foundries (1:13). Smaller fabless companies often possess low bargaining power in these negotiations, placing them at a disadvantage position (4:14). Foundries tend to prioritize companies that can fully utilize their production capacity. Larger fabless firms with strategic partnerships and significant customer status could feasibly obtain production capacity and favourable pricing (3:5). Another disadvantage is the reliance on the foundry's process capabilities and the assembly plant's packaging capabilities, leading to scenarios where well-designed products lack appropriate manufacturing support. Consequently, the Fabless-foundry model might face limitations during iterative advancements

(1:5, 1:26). Furthermore, foundries usually provide existing process manufacturing platforms, requiring fabless firms to design compatible products. This situation may result in products that are similar to those of competitors, thus reducing competitive advantage (3:4). From a business perspective, fabless companies are heavily dependent on supplier relationships. Smaller fabless firms risk exploitation by suppliers who may prioritize larger clients, introducing vulnerabilities in the supply chain (2:1). End customers, who expect stable and reliable production, prefer fabless companies with their own production capabilities to mitigate supply risks (2:2).

Proposition 17.3 ***(1.1, 6.1)*****:** IDMs and foundries rely heavily on long-term partnerships with suppliers of advanced manufacturing equipment and raw materials, whereas fabless companies primarily depend on and are restricted by stable and collaborative relationships with suppliers, foundries, and assembly plants, especially the process capabilities of existing process platforms and packaging capabilities from assembly plants.

Foundries have several advantages. By offering process manufacturing services to multiple fabless firms and design houses, foundries can achieve synergies and reduce marginal production costs, thereby lowering overall costs. After recovering initial investments, foundries can leverage their cost advantages to compete with IDMs in developing advanced process nodes (1:6, 1:7). With adequate funding and available capacity; foundries can assist fabless firms in optimizing and manufacturing new designs. Additionally, foundries maintain significant bargaining power over small fabless firms. Their manufacturing platforms can cater to a wide range of needs, reducing the necessity for developing new process lines (4:9).

Proposition 17.4 ***(4.2)*****:** Both fabless and foundry focus on efficiency; the collaboration of these two business models enables the production of semiconductor products at lower costs with faster time-to-market due to the flexible, innovative, specialized nature of fabless, and achieves synergies and reduces marginal production cost due to the scalability, technological expertise of the foundry.

Proposition 17.5 ***(5.1, 7.1)*****:** IDMs and foundries maintain close and direct interactions with their loyal clients and suppliers, large OEMs dominate IDM's customer segmentation, whereas fabless has higher customer turnover rates and lower customer loyalty because of its innovation-driven feature.

Considering the lengthy development cycles inherent in the semiconductor industry, strategic foresight is crucial for foundries. They must accurately predict the future market performance of products. If products do not have a future market, the substantial upfront investment and associated time costs are catastrophic to foundries (1:8, 1:9), which supports Proposition 15.1.

The summarized comparison of advantages and disadvantages of IDM, fabless and foundry model is listed in Table 6.3.

Table 6.3: Comparison of advantages and disadvantages of IDM, fabless and foundry

Model	Advantages	Disadvantages
IDM	- Retains all core competencies internally from design to manufacturing to packaging and testing - Facilitates resource integration efficiently to respond to customer demands rapidly, to enhance production efficiency and to reduce costs - Extensive customer base with integrated solutions beneficial for small and medium-sized customers, and high switching costs for long-term customers - Ability to leverage existing customer relationships for new products - Can strategically outsource mature, low-margin products while retaining core business	- Heavy asset nature requiring substantial upfront investments and minimal initial return on investment; can take up to a decade to break even - Challenges in maintaining investment flexibility, low capacity utilization leading to financial losses if the investment is premature and losing market opportunities if the investment is delayed - Risk of overextending business without adequate technical foundations

Model	Advantages	Disadvantages
Fabless	- Light asset nature with no significant investments in fixed assets makes it higher operational flexibility - Financially favourable returns through partnerships with foundries and assembly facilities - Ability to reduce orders during market downturns to relieve financial pressures - Flexibility to explore and penetrate competitive niche markets with support from foundries, customers, and supply chain	- Lack of control over the entire production process - High outsourcing costs during market shortages - Dual challenge of managing costs and securing sufficient production capacity - Low bargaining power for smaller companies in foundry negotiations - Reliance on foundry's process and assembly plant's packaging capabilities, causing the potential for similar products to competitors - Heavy dependence on supplier relationships, with risks of exploitation and supply chain vulnerabilities
Foundry	- Achieves synergies and reduces marginal production costs by serving multiple fabless firms and design houses - Cost advantages after recovering initial investments - Ability to assist fabless firms in optimizing and manufacturing new designs - Significant bargaining power over small fabless firms - Manufacturing platforms cater to a wide range of needs, reducing the need for new process lines	- Requires strategic foresight to predict the future market performance of products - Substantial upfront investment and time costs if products lack future market potential

6.3.2. Competitive dynamics and strategic adaptations in the semiconductor industry

The role of technological advancement in shaping competitive dynamics

Technological innovation is the core competitive pressure and driving force in the semiconductor industry. Developing and applying new technologies can significantly enhance product performance and reduce costs, thereby providing a competitive advantage. Technologically advanced companies can capture market share by introducing high-performance, low-power products. Additionally, technological innovation can explore new markets and application areas, creating new growth opportunities. However, due to the rapidly evolving nature of the semiconductor industry, considerable capital investment is crucial. Continuous investment in R&D is necessary for companies to maintain their technological edge amidst fierce competition (2:7, 6:4). The emphasis on R&D expenditures intensifies the argument in Proposition 14.2.

When emerging trends drive industry-wide transformations, the pressure of technological innovation also impacts the market end (1:17). According to the Cyclical Model of Technological Change, a new technological innovation causing discontinuity can trigger design competition among numerous companies until a dominant design emerges. For instance, the rise of electric vehicles has significantly reshaped the industry landscape. However, in the semiconductor industry, only a few companies achieve dominant design status, while the rest face severe product homogeneity issues. For small fabless companies, this homogeneity poses immense pressure. They need to balance performance and price, and in the short term, they may only survive by reducing costs, as achieving significant performance breakthroughs quickly is challenging (4:16). Cost reduction, however, has its limits. As only one part of the industry ecosystem, fabless companies must compress costs throughout the supply chain step by step, eventually distributing the cost reductions among all suppliers, which is not a sustainable solution (4:17). Larger fabless companies, however, have more strategic options. They can choose to pause projects for highly competitive products and instead focus on launching next-generation products in related markets to alleviate competitive pressure (3:16). Alternatively, in a highly competitive and capacity-constrained environment, they can secure production stability by partnering with at least two foundries to manufacture their core products (3:19).

Infineon, as an IDM company, provides a representative example to support Proposition 14.1. Initially, Infineon focused on mobile communication and memory chips. However, due to competitive pressures, it realized its iteration cycle was slower than that of companies like Samsung. Consequently, Infineon strategically shifted its focus to the power semiconductor sector, which has longer iteration cycles. While power semiconductors may not yield high short-term profits like logic IC semiconductors from companies such as NVIDIA, the power semiconductor market is relatively stable and predictable (5:10). By assessing its technological capabilities, capital, and market positioning, Infineon managed to achieve VRIN qualities, securing a sustainable competitive advantage. This strategic transformation proved to be successful.

Proposition 18.1 ***(14.1)*****:** IDMs, fabless, and foundries' competitive pressure can be reduced, their competitive edge can be revitalized, and the company's resilience can be enhanced by strategic reorientations, which transfer the R&D and investment from the current focal business and product to another potentially promising field, broaden and diversify business lines towards high-performance and high-margin segments or niche markets to avoid product homogeneity and achieve VRIN qualities.

IDM's strategic adaptations to the competitive dynamics

A standard strategic adjustment for IDM companies involves balancing internal production with outsourcing. When internal capacity is insufficient, allocating this capacity to products with relatively high-profit margins and high technical barriers is more cost-efficient, while outsourcing low-margin and low-profit products to foundry companies. The key is to balance this ratio effectively (1:10, 1:11). Similarly, IDM companies must differentiate between existing and new products. For mature existing products, the focus is on future sales and profit margins, making cost reduction a more targeted strategy. Conversely, new products, which cannot initially achieve high-profit margins, primarily aim to capture market share and weaken competitors' positions. Continuous cost reductions can be then applied as new products mature, facilitating the transition from old to new products (1:28). For instance, Infineon allocates part of its production internally while outsourcing some to other foundries or IDMs.

Proposition 19.1 ***(9.1)*****:** IDMs must balance internal production with outsourcing from various technologies while differentiating the existing and new products regarding their positions in the markets to diversify companies' revenue streams and expand the market reach.

The semiconductor industry, characterized by cyclicality and high volatility, requires strategic foresight. As a heavy asset IDM model, it requires collaboration across various departments—such as functional departments, finance, and headquarters—to develop short-term (1-2 years) and long-term (3-5 years or more) strategic plans. These plans should include future technology roadmaps, market potential products, and capacity planning (1:19). The industry is also susceptible to significant market disruptions. For instance, the COVID-19 pandemic 2020 led to a market downturn, with supply exceeding demand and companies reducing production to cut costs. However, when the market recovers, failure to promptly resume production or address capacity constraints can lead to inventory shortages and missed market opportunities (1:18). Therefore, during market downturns, if sufficient cash flow is available, doing the opposite by operating fabs at full capacity can ensure timely sales when the market rebounds.

Proposition 19.2 ***(15.1)*****:** The semiconductor companies, whether IDM, fabless or foundry, must precisely predict the correct technical pathways at critical junctures to avoid undeveloped markets causing technological stagnation, rapidly and independently advance product and process development and innovation, continuously update strategies according to the market, and invest from the vision of the next five to ten years. Strategies must carefully balance long-term strategic investments with short-term market performance while always being prepared for major market disruptions.

The primary competitive advantage for logic IC semiconductors lies in more advanced process technologies. Currently, the major logic semiconductor IDM companies are Intel and Samsung, as establishing fabs and investing in process technology R&D require enormous capital. This industry posture is why leading companies like NVIDIA, AMD, and Qualcomm predominantly operate in a fabless model (3:10). Case studies have highlighted Intel's recent decline as an IDM and its missed opportunities in the mobile market. A deeper reason lies in the nature of logic IC semiconductor companies: they typically focus on a single technological route, leading to process singularity (4:28). This singularity is reflected in a narrow application scope, high market competition, and limited market share. Recognizing this, Intel adopted the IDM 2.0 strategy, establishing new fabs and Intel Foundry Services (IFS) to reduce operational risks and enhance flexibility between design and manufacturing departments (5:5). This strategic adaptation was summarized in Proposition 15.2. Nonetheless, Intel's new fab investments face significant future capacity utilization pressures, which need strategic foresight regarding current and future market potentials (5:7).

For discrete devices such as power semiconductors and other specialized process products, design-related intellectual property (IP) is less significant. The manufacturing process requirements are less stringent and advanced, with core IP residing in the production process. Additionally, the cost of establishing related fabs is lower, driving most companies to operate in an IDM model, as illustrated by the Infineon example (5:6). Furthermore, entry barriers in the power semiconductor sector are relatively low, avoiding the process technology monopolies seen in the logic semiconductor sector. If new processes emerge in this field, it implies that most companies start on an even playing field, allowing for the establishment of new fabs for these processes (3:12). When IDM companies hold a certain market advantage in a specific specialized process, it can create a virtuous cycle in capacity planning: during promising market conditions, having an internal foundry provides flexible pricing and production control for core businesses, with outsourcing to other foundries as needed (5:15). During market downturns, they can undertake contract manufacturing for other companies while investing in upgrades for existing production lines and process R&D. Additionally, they can diversify into less competitive niche markets for additional revenue streams (3:15, 5:11). The statement about capacity planning and market expansion has been mentioned in Propositions 16.4 and 18.1, respectively.

Strategic considerations for fabless companies

As previously emphasized in Proposition 18.1, the heterogeneity of business and products is crucial for companies, whether operating under the IDM or fabless model. Companies need to aim for extensive market coverage, as relying solely on a single product is not sustainable for a semiconductor company. Large fabless companies typically design a broad range of platform-oriented products suitable for several major applications rather than developing a chip for a particular application scenario. In contrast, small fabless companies, whose design capabilities may not match those of larger firms, can target niche markets by developing products for specific scenarios. Although the overall performance of these products may be slightly inferior to those produced by large companies, they can still be highly effective in specific applications (2:4).

Fabless companies should consider establishing deeper relationships with foundries to secure a more stable production capacity in a competitive market. This relationship can be achieved through cross-shareholding or mutual investments (2:3). In collaborations between fabless companies and foundries, the focal points differ. Foundry companies prioritize the ability of fabless companies to maximize the utilization of their production capacity over the R&D investments and core IP holdings of fabless companies (4:25). Specifically, fabless companies in the specialized devices sector, upon accumulating sufficient capital, can consider establishing their own fab to transition into an IDM model. Although the iteration cycles of these semiconductors are longer compared to logical semiconductors, continuous evolution and improvement are still observed, with processes changing from one day to the next (3:9). Sole reliance on foundry cooperation can present coordination issues and limit process technology to the foundry's established process platforms (3:6). In a highly competitive market environment, fabless companies generally have low bargaining power when dealing with foundries, often having to compromise, reduce costs, or place more orders, which results in a loss of initiatives and strategic advantage (3:7).

Proposition 20.1 ***(14.3)*:** Unlike IDMs, foundries with non-competitive stances and relative technological advantages are more likely to become partners for fabless companies, but securing a more stable and advanced production capacity needs the establishment of deeper relationships such as cross-shareholding, mutual investments or DTCO.

Fabless companies of a certain scale can achieve greater flexibility by distributing their manufacturing production across multiple foundries. The allocation allows them to mitigate risks associated with capacity issues at a single foundry by switching to another (3:8). However, products manufactured by different fabs require second-source verification, which is a lengthy process. As highlighted in Proposition 17.3 about the importance of supply chain stability, for small fabless companies, an abrupt change in foundries can destabilize the supply chain, adversely impacting their market position and making them reactive rather than proactive (4:15).

Strategic capacity planning and customer relationship management in foundry operations

In the operation of a foundry, detailed and comprehensive capacity planning based on market demand and technological advancements is imperative. This process involves forecasting future product demand and assessing market profitability (1:14). Concretely, foundries evaluate whether the market possesses sufficient demand to utilize their production and the corresponding profit margins of these products. Both scenarios of high volume with low profitability and low volume with high profitability result in lower return on investment. Foundries with high bargaining power will evaluate potential fabless partners regarding which companies can maximize value creation. Moreover, due to the significant operating and depreciation costs, foundries must strategically balance orders between large and small customers. Orders from large customers stabilize capacity utilization but also entail risks, especially during economic downturns when substantial order reductions can lead to significant capacity underutilization and surplus. For example, TSMC, having learned from previous experiences, allocates a significant portion of its capacity to large customers while reserving part for small to medium-sized customers and maintaining a small capacity buffer as an emergency reserve (4:12). This strategy is a typical example of capacity planning, as concluded in Proposition 16.4, which ensures flexibility to accommodate high-priority orders if market conditions change, thus mitigating risks and maintaining continuous production line operation.

Regarding the alignment of design and process technologies, the fabless and foundry models show certain limitations. Collaboration between foundries and major customers has evolved from simple contract manufacturing to more integrated DTCO initiatives to address rapid technological advancements. An illustrative example is the partnership between TSMC and Apple, where TSMC's initial process technology was insufficient to support Apple's designs. The resolution involved mutual adjustments, with Apple modifying its designs and TSMC advancing its process technology to achieve compatibility. Presently, foundries may establish dedicated production lines for specific major customers as part of customer relationship management (CRM), defining these processes as exclusive and confidential, known as Customer Owned Tooling (COT), rather than subsidiary processes within the foundry (4:2, 4:6). This approach underscores the strategic importance of maintaining long-term, stable relationships with major customers within the foundry companies and serves as the illustration of Proposition 16.1 and Proposition 20.1.

6.3.3. Key performance indicators in evaluating IDM, fabless, and foundry model

For IDMs, expanding product lines to achieve higher market coverage is critical, making market share a vital performance indicator (1:20, 2:13, 6:6). Additionally, revenue and profit-related metrics, such as EBIT, gross margin, revenue size, and their respective growth rates, effectively reflect a company's financial health, profitability, and cost control capabilities (1:20, 3:20, 5:13, 6:6). Leading semiconductor companies such as Intel, Texas Instruments, and Infineon exemplify this, with annual revenues typically exceeding $10 billion (1:20). For IDMs with heavy asset investments in fabrication plants (fabs), metrics related to capacity utilization, production efficiency, process development, and optimization are also crucial evaluation criteria (3:20, 5:14, 6:6).

Similarly, fabless companies prioritize market share but focus on specific niche markets (2:14, 4:24). Indicators such as sales revenue, profit margins, the number of core IPs, and R&D investment ratios reflect the core competitiveness and innovation ability of fabless firms (1:21, 3:22, 4:24, 6:6). Fabless companies face significant challenges in supply chain management; thus, supply chain stability and bargaining power with upstream and downstream partners serve as implicit indicators of operational efficiency and management performance (3:21, 4:24).

For foundries, which also involve heavy asset investments, profitability is the primary focus. Given the substantial initial capital investments in equipment, personnel, and the high costs associated with maintenance, depreciation, and utilities, profitability is a key indicator of a foundry's financial health and technological capability (1:22, 2:15). Capacity-related metrics are equally crucial as the market assesses foundries based on their production capacity and the capacity utilization rates required to ensure profitability (2:16, 4:26, 6:6). Furthermore, the technological features of a foundry's processes and the advancement of its process nodes relative to other foundries are important evaluation metrics (4:26). Lastly, the financial backing and support behind foundries are important indicators of their risk resilience (4:26), whether it involves private investment or government policies. Notable examples include the U.S. CHIPS Act of 2022, which allocated billions of dollars to enhance semiconductor research and manufacturing, and China's 2023 initiatives to accelerate the development of AI chips.

Proposition 21.1: The common and explicit key market performance indicators for business models include market share, revenue size, profitability, and R&D investment ratios. Capacity utilization, production efficiency, and process development for IDMs and foundries while core IP count and niche market shares for fabless. The implicit indicators, such as supply chain stability, bargaining power, financial health and risk resilience, are equally significant to the three business models.

7 Discussion

This chapter begins with a summary of key findings and the confirmation of the propositions developed throughout the study. The answers to the main research question and sub-questions will be discussed according to the insights from the comparative analysis, case studies, and interview thematic analysis. Afterwards, the generalizability of the findings will be evaluated by pointing out their applicability across different contexts. Theoretical and managerial contributions will be elaborated to show the study's significance and practical implications. The chapter will also discuss the current study's limitations and provide recommendations for semiconductor companies with different business models. Finally, a reflection will be given regarding the research process and personal learning outcomes.

7.1. Summary of key findings

This study aims to explore the competitive dynamics, strategic adjustments and market performance of IDM, fabless and foundry business models in the semiconductor industry. The research methodology mainly includes comparative analysis, case study and interview thematic analysis. In this study, the literature review is also used as a data source to obtain qualitative data from it to form a methodological triangulation with the above three analysis methods. In the triangulation, the qualitative data and the results obtained by the analysis methods are cross-validated to improve the reliability and accuracy of the final results and conclusions.

Through the literature review, the existing research mainly focuses on the characteristics, supply chain, market performance prediction using mathematical models, specific internal business model operation-related analysis and future industry trends from the perspective of a single business model. However, few studies compare the three business models in parallel to study how their strategic differences in response to competitive postures affect their market performance, resulting in a knowledge gap. At the same time, when studying the differences between industry business models, it is found that Intel, AMD and TSMC are not only remarkably representative of the three business models but also because these three companies have a lot of interactions in the process of development that are not limited to competition, cooperation or transformation. Therefore, they were selected as the analysis objects of subsequent case studies. Given the unique nature of the research topic, Eisenhardt's case study methodology was selected for its advantage in comprehending phenomena and generating propositions within the context of exploratory research. The literature review uses three existing theoretical frameworks, namely the Cyclical Model of Technological Change, the Resource-Based View, and the Dynamic Capabilities Framework, to demonstrate the theoretical linkages between competitive dynamics in the semiconductor industry and strategic adaptations within enterprises. In the subsequent analysis of studying the semiconductor industry, it is found that the competitive situation and dynamics of the industry, as well as the strategic initiatives of enterprises and their impact on market performance, are consistent with the descriptions of these three theories on the impact of discontinuous technology on the market and competition, the conditions and qualities that enterprises need to meet in order to achieve sustainable competitive advantages, and the dynamic capabilities that enterprises need to processes to cope with rapidly changing environments. The specific theoretical contributions will be discussed in detail in the following sections.

In the comparative analysis, BMC is used to compare the IDM, fabless and foundry business models, specifically from the perspective of nine criteria in four orientations. The detailed comparison content can be viewed in Table 4.1. In this step, 14 propositions were proposed for these nine criteria. The list of propositions can be viewed in 4.2.

For example, these propositions compare the similarities or differences between IDM and fabless in key partners or describe the unique cost structure of the IDM model. Afterwards, the C-STOF model was used to conduct a qualitative analysis of Intel, AMD, and TSMC from the perspectives of customer value, service, technology, organization, and finance. In each perspective, a C-STOF dashboard is given to visually compare the similarities or differences between the three companies, as shown in Figure 4.4 as an example. The insights gained from the C-STOF model analysis will provide reference and direction for the case analysis in the next chapter, such as the strategy adopted by a single enterprise to confront market competition in a certain period of time. The reason why the BMC and C-STOF model methods are combined for comparative analysis is that the use of BMC to conduct a macro analysis of the overall business model in the industry and then the C-STOF model to analyze the specific enterprises at the micro level can provide a comparative analysis that takes into account both breadth and depth, thereby obtaining more convincing and representative conclusions.

The case study adopts Eisenhart's case study method. However, the case study is only part of the methodology for this study, and the research questions have been established, the case companies have been selected, the data collection methods have been defined, and the data collection has been completed at the beginning. Therefore, the case studies were directly conducted in the form of within-case and cross-case studies, following the framework of Eisenhart's method but not executing each step in detail in sequence. In the within-case study, the major events with reference significance in the historical development of each company in response to competitive dynamics are elaborated in detail, and propositions are proposed for indicative content that can provide answers to sub-question 3. The cross-case study describes and analyzes the interactive events between the three companies mentioned above and proposes propositions. Finally, all the propositions proposed in the case analysis and the comparative analysis in the previous chapter were modified and integrated. The complete list of propositions can be found in the table 5.2.

This study used a semi-structured interview model to interview six experts in the semiconductor industry as the last step of the methodology. The final interviewees met the interview criteria proposed in Table 2.2 to ensure that they had rich experience in the semiconductor industry and could provide valuable and reliable insights. ATLAS.ti qualitative analysis data was used as an aid in the interview thematic analysis, and the relevant interview excerpts were coded so that they could be easily and quickly integrated into the thematic analysis. Finally, the final propositions were integrated and modified based on the analysis results and all the propositions and findings obtained in the previous comparative analysis and case study. The complete list of propositions will be given in the next section.

7.2. Proposition development

The following Figure 7.1 illustrates the complete proposition development process in this research, comprising five main steps. In the initial comparative analysis of the first step, a total of 14 propositions were proposed for four orientations. These propositions primarily summarized the characteristics, commonalities, and differences of semiconductor business models in nine elements. The detailed list of propositions in the first step can be found in Table 4.2. In the second step, during the case studies, 18 propositions were proposed in both within-case studies and cross-case studies. Considering that some propositions were repetitive or could be combined, the third step involved revising and organizing the propositions from the second step, resulting in 9 propositions. The list of propositions in the third step can be found in Table 5.1. All propositions derived from the first and third steps were subjected to triangulation through interview theme analysis, achieving further optimization and integration, ultimately obtaining 14 propositions. Finally, all propositions were integrated and analyzed, resulting in the final proposition list.

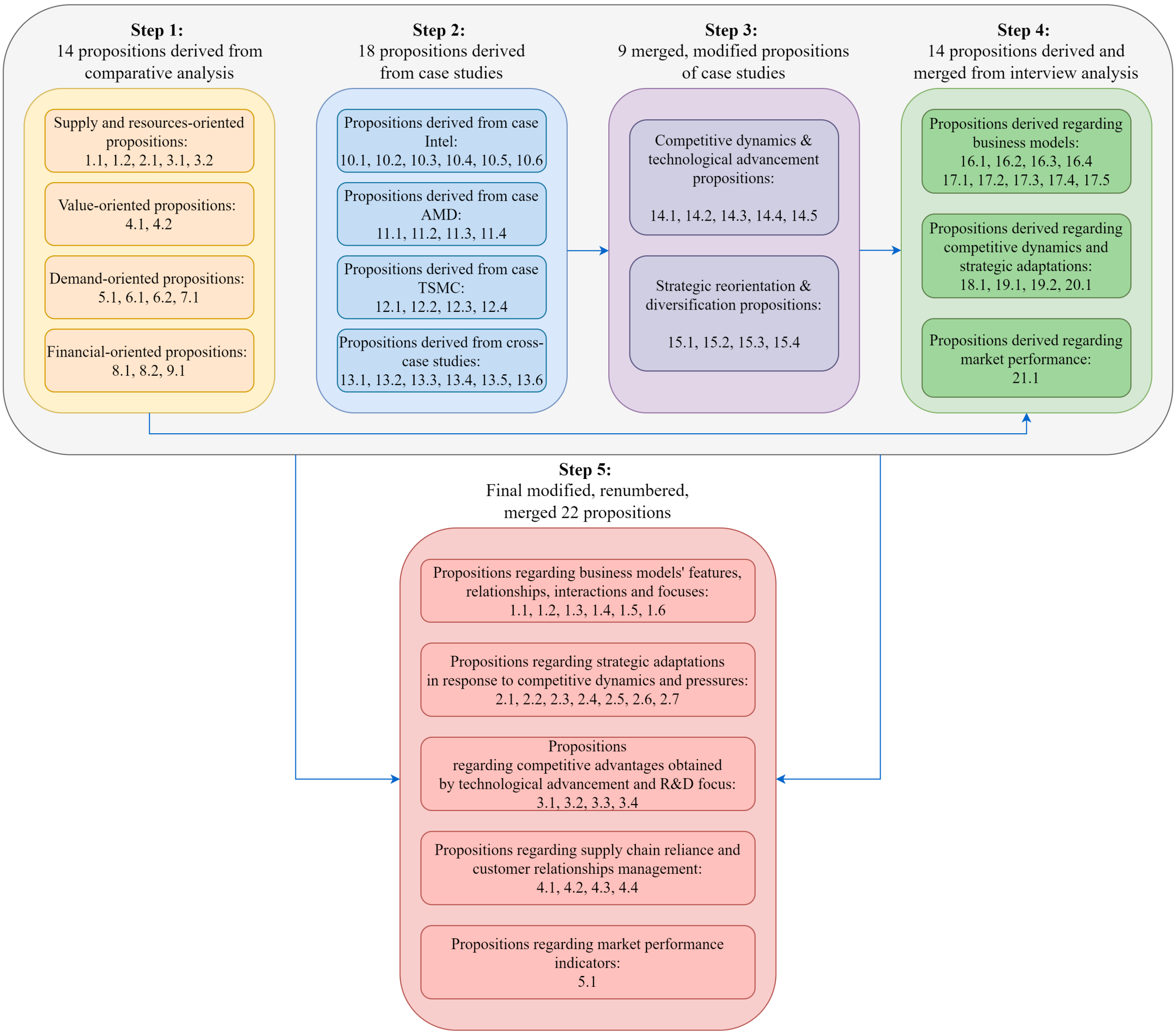

Figure 7.1: Evolution of the propositions

After analyzing the qualitative data from interview thematic analysis and integrating insights from comparative and case studies, the propositions have been summarized and renumbered. This involved merging, modifying, and consolidating propositions. The final proposition list is organized into five categories:

- Business models' features, relationships, interactions, and focuses
- Strategic adaptations in response to competitive dynamics and pressures
- Competitive advantages obtained through technological advancement and R&D focus
- Supply chain reliance and customer relationship management
- Market performance indicators

A total of 22 propositions are proposed from the comparative analysis, case analysis and interview thematic analysis. Some propositions may overlap across multiple categories; however, each proposition is assigned to a single category for clear examination. The italicized numbers in brackets indicate the original proposition numbers. The final proposition list is presented in Table 7.1.

Table 7.1: Categorized, modified, merged and renumbered proposition list from comparative analysis, case studies and interview data

Categorization	Propositions	
Business models' features, relationships, interactions and focuses	**1.1** *(2.1)*	The breadth of business covered by the cooperative model between fabless companies and foundries basically matches the business scope traditionally covered by IDMs without the need for vertical integration.
	1.2 *(16.2)*	Within the same semiconductor business sector, the relationships between fabless companies and foundries are characterized by a non-competitive, complementary, and mutually beneficial collaboration, while the relationship between fabless companies and IDM is competitive regarding market share and technological advancement.
	1.3 *(16.3)*	Fabless companies in the logic semiconductor field are more dependent on core IP and advanced EDA tools than IDMs, while fabless companies in the power semiconductor field emphasise stable outsourcing production due to the distinct technical features, architectures and focus.
	1.4 *(17.2)*	The heavy asset nature of IDMs indicates the high fixed and variable costs, which poses the significance of investment flexibility that balances the cost control and investment cycles to keep pace with market rhythms, yet the Fabless-foundry collaboration model shows a more flexible and cost-effective approach.
	1.5 *(17.4)*	Both fabless and foundry focus on efficiency; the collaboration of these two business models enables the production of semiconductor products at lower costs with faster time-to-market due to the flexible, innovative, specialized nature of fabless, and achieves synergies and reduces marginal production cost due to the scalability, technological expertise of the foundry.
	1.6 *(20.1)*	Unlike IDMs, foundries with non-competitive stances and relative technological advantages are more likely to become partners for fabless companies, but securing a more stable and advanced production capacity needs the establishment of deeper relationships such as cross-shareholding, mutual investments or DTCO.
Strategic adaptations in response to competitive dynamics and pressures	**2.1** *(14.4)*	Due to the cyclical and technological-intensive nature of the semiconductor industry, IDMs' systematic and structured strategies that are associated with taking innovation and production cycle factors into account effectively maintain the competitive edge, while the strategic frameworks could be undermined by delays or stagnation of technological advancements.
	2.2 *(14.5)*	Inadequate participation in emerging markets can lead to significant financial losses and market share declines for IDM companies with relatively low flexibility.
	2.3 *(15.2)*	IDM's strategic readjustment to include external collaboration, ecosystem building, and the spin-off or the divesting of foundry services to transit to fabless or separately operating the design and manufacturing sector can enhance operational agility, providing financial relief and focus on innovation, thereby regaining competitive advantage after stagnation.
	2.4 *(15.4)*	IDM can leverage its experience in manufacturing to build new fabs to compete in foundry services with other foundries.
	2.5 *(16.4)*	The heavy reliance on orders drives foundries and IDMs with foundry service to make detailed plans for existing and future production capacity to achieve break-even or maintain profitability.
	2.6 *(19.1)*	IDMs must balance internal production with outsourcing from various technologies while differentiating the existing and new products regarding their positions in the markets to diversify companies' revenue streams and expand the market reach.

Categorization	Propositions	
	2.7 *(19.2)*	The semiconductor companies, whether IDM, fabless or foundry, must precisely predict the correct technical pathways at critical junctures to avoid undeveloped markets causing technological stagnation, rapidly and independently advance product and process development and innovation, continuously update strategies according to the market, and invest from the vision of the next five to ten years. Strategies must carefully balance long-term strategic investments with short-term market performance while always being prepared for major market disruptions.
Competitive advantages obtained by technological advancement and R&D focus	**3.1** *(14.2)*	Achieving advanced next-generation process node technology rapidly through high R&D expenses and efficiency to possess first-mover advantages while balancing innovation and cost-effectiveness when developing it and addressing yield issues is crucial for IDM and foundries to gain market leadership and define future competitive trajectories.
	3.2 *(15.3)*	Considerable investments in R&D and targeted strategic acquisitions of companies with complementary and advanced technologies for IDMs and fabless can significantly enhance competitive positioning through technological advancements and superior product offerings.
	3.3 *(16.1)*	For IDM and fabless-foundry models, the degree of matching between design and process and implementing design technology co-optimization will affect product performance and time to market, thus affecting product competitiveness.
	3.4 *(18.1)*	IDMs, fabless, and foundries' competitive pressure can be reduced, their competitive edge can be revitalized, and the company's resilience can be enhanced by strategic reorientations, which transfer the R&D and investment from the current focal business and product to another potentially promising field, broaden and diversify business lines towards high-performance and high-margin segments or niche markets to avoid product homogeneity and achieve VRIN qualities.
Supply chain reliance and customer relationships management	**4.1** *(3.2)*	The highly specialized global supply chain and reliance on a skilled workforce are equally significant for IDMs, foundries, and fabless companies.
	4.2 *(17.1)*	By internally covering all core steps of developing a semiconductor product, the vertical integration IDM model enables deeper penetration to end-markets and supply chain participants and continuously providing holistic and reliable solutions for long-term customers who are seeking a single-source solution due to the high switching costs accumulated by user habit.
	4.3 *(17.3)*	IDMs and foundries rely heavily on long-term partnerships with suppliers of advanced manufacturing equipment and raw materials, whereas fabless companies primarily depend on and are restricted by stable and collaborative relationships with suppliers, foundries, and assembly plants, especially the process capabilities of existing process platforms and packaging capabilities from assembly plants.
	4.4 *(17.5)*	IDMs and foundries maintain close and direct interactions with their loyal clients and suppliers, large OEMs dominate IDM's customer segmentation, whereas fabless has higher customer turnover rates and lower customer loyalty because of its innovation-driven feature.
Market performance indicators	**5.1** *(21.1)*	The common and explicit key market performance indicators for business models include market share, revenue size, profitability, and R&D investment ratios. Capacity utilization, production efficiency, and process development for IDMs and foundries while core IP count and niche market shares for fabless. The implicit indicators, such as supply chain stability, bargaining power, financial health and risk resilience, are equally significant to the three business models.

7.3. Answers to research questions

This study lists the main research question and four sub-questions in the 1.3.1 section. The main research question will be answered by first solving the sub-questions and the integrated results.

SQ1: *What are the essential differences between IDM, foundry and fabless business models?*

This sub-question is answered by comparing the results of the nine criteria of the respective business models obtained using the BMC method in the analysis, see Table 4.1. For key partners, IDM and foundry with manufacturing capabilities, they have strong partnerships with production equipment manufacturers and raw material suppliers. IDM and fabless also include design businesses, so they rely on software providers that can provide EDA to form partnerships. According to Proposition 1.1 and the discussion of key activities, fabless is responsible for design and sales, and the foundry is responsible for production, manufacturing, packaging and testing. The combined business scope covered by these two is exactly the same as that covered by an IDM. Therefore, fabless and foundry are partners of each other. The key resources shared by these three business models are highly skilled human resources. For vertically integrated IDM, it has both design and production capabilities, which is one of its key resources. At the design level, IP cores are undoubtedly important resources for IDM and fabless. Moreover, since fabless has no manufacturing facilities and foundries rely on manufacturing orders to survive, the partner network of the two is also a key resource.

At the value proposition level, the integrated nature of IDM enables it to coordinate and collaborate design and production sufficiently, focus on overall solutions, and provide integrated products and services. Fabless focuses more on flexibility and innovation. Since IP cores are its core value, customers expect fabless to provide more cutting-edge performance and efficiency. However, efficiency requires the joint efforts of fabless and foundries, so the value of foundries is reflected in their production efficiency, scalability, and advanced process technology.

The flexibility of fabless leads to a higher customer turnover rate than IDM. IDM and foundries are more likely to establish long-term, stable, loyal customer relationships than fabless. In terms of channels, all three adopt the B2B model. The channel for fabless to establish cooperation with foundry is mainly through the open process service platform provided by foundry, using existing process nodes to provide manufacturing services for fabless. In contrast, IDM only needs to adopt an adaptive go-to-market strategy and use direct sales or designated distributors to sell finished semiconductor products. Regarding customer segmentation, IDM and fabless mainly serve large OEMs, and there is no apparent difference in their specific application fields, including but not limited to telecommunications, automobiles, and cloud services. Foundry's customers are mainly fabless and IDM's outsourced manufacturing business.

In the rapid-iterative and technology-intensive semiconductor industry, R&D expenditures account for a large part of the cost structure for all three, and for the asset-heavy business model of IDM and foundry, capital and operating expenditures in production also require considerable costs, and fabless needs to spend for the cost of IP core development and IP licensing. IDM has a broader source of income in the revenue stream because its chips can be widely used in consumer electronics, automobiles, integrated solutions, and IoTs. Most fabless develops chips for a single field, and its outsourcing expenses for product manufacturing will serve as a source of income for the foundry.

SQ2: *How do competitive dynamics relate to strategic adaptations in the semiconductor industry?*

This question is addressed through the theoretical linkages of competitive dynamics and strategic adaptations within the semiconductor industry, as stated in Section 3.5 and further supported by the thematic analysis of interviews. The interaction between these concepts is not simply a linear cause-and-effect relationship but a complicated, mutual relationship influenced by technological advancements and market demands. Anderson and Tushman's Cyclical Model of Technological Change aptly explained this relationship. After the emergence of new discontinuous technology, and when it is developed into a viable application by a company and subsequently accepted by the market, indicates a disruption in existing competitive dynamics, urging other enterprises to modify and adjust their strategies to align with new market trends.

For instance, the advent of AI and the electric vehicle industry presents such disruptive technologies, driving companies to shift their strategic focus towards developing new AI computing chips and automotive-grade chips for electric vehicles (4:21). In AMD's case study, AMD strategically redirected its resources and efforts towards the R&D of high-performance computing chips and the expansion of data centre businesses after recognizing the future potential of high-performance computing. This strategic shift allowed AMD to seize market opportunities in the contemporary AI era and also indicated how the enterprise responded to competitive dynamics through strategic adaptation.

Moreover, the strategic adaptations of enterprises can, in turn, influence the industry's competitive dynamics. The emergence of the fabless and foundry business models shows that companies that adopted the fabless-foundry collaborative model and attained competitive advantages have somewhat impacted the industry's business model dynamics. Consequently, increasing companies are inclined to transition or spin off their manufacturing facilities to become fabless business models with a light asset and a more flexible nature to achieve cost efficiencies.

SQ3: *How do the competitive dynamics mutually influence the strategic adaptations of the three business models within the semiconductor industry?*

This question can be addressed through the results of the Intel, AMD, and TSMC case studies. For IDM, fabless, and foundry business models, as articulated in Proposition 14.1, when confronted with highly competitive product markets or specific technological tracks, these companies can relieve competitive pressure via strategic reorientations which involve reallocating R&D resources and investments from heavily contested business areas, including products and services, to other potential fields. Given the diversity of semiconductor products and the complexity of semiconductor processes, these companies can also expand their business lines to cover more high-performance and high-profit market segments or niche markets. However, enterprises across all three business models must invest heavily in technological advancements and R&D to contend with the technology-driven and technology-intensive competitive dynamics, leading to rapid iteration within the semiconductor industry, as predicted by Moore's Law. Any strategic misstep resulting in technological stagnation can lead to failures in both the current and subsequent competitive cycles, potentially causing significant losses or even threatening the company's survival. For example, as highlighted in the Intel case study, stagnation at the 14nm process node, with no updates for seven years, led to Intel being overtaken by other IDM companies and fabless-foundry models. Therefore, IDM, foundry, and fabless companies need to make substantial R&D investments and improve efficiency in manufacturing and design while accurately predicting the correct technological path at critical moments to quickly achieve the next generation of advanced process node technology or higher-performance chip designs, thus gaining a first-mover advantage in market competition.

As frequently emphasised, the semiconductor industry's cyclical nature implies that competitive dynamics differ between economic upturns and downturns. During upturns, competition within the industry is intense, and manufacturing faces greater pressure to maintain sufficient product supply. For IDM and foundry companies, this requires strategic coordination, allocation, and planning of production capacity-related issues. Fabless companies face an even more severe situation because the industry's limited capacity means that their partnered foundries cannot consistently guarantee stable and continuous capacity, giving fabless companies lower bargaining power. This drawback pushes fabless companies to make strategic adjustments in securing capacity, such as adopting a strategy of collaborating with multiple foundries simultaneously, although this depends on the fabless company's size and financial strength. However, during economic downturns, competition is less intense, and the pressure shifts more to the sales end. IDM and fabless companies need to consider sales strategies to sell products quickly, as rapid iteration can render semiconductor products outdated, leading to losses, and maintaining inventory incurs significant costs. Intel's Tick-Tock strategy leverages the industry's cyclicality to incrementally update and optimise technology, though it was ultimately abandoned due to technological stagnation. In summary, when responding to competition dynamics, these three business models must consider economic upturns and downturns and adopt targeted strategies, requiring strategic foresight to even prepare for downturns during upturns.

Competitive dynamics essentially refer to companies contending for existing market share, where a higher market share indicates a larger customer base. All three business models emphasise improving product quality to secure long-term, stable, loyal customer relationships and reduce costs to gain more profits. However, fabless companies, driven by innovation and characterised by flexibility, do not have as stable a customer base as IDM and foundry companies. Therefore, fabless companies' strategies focus more on high-performance and high-profit areas and constantly reduce costs through negotiation with foundries and upstream and downstream suppliers, distributing costs across the entire supply chain to gain a competitive edge. As mentioned in the comparative analysis of cost structures, the R&D cost of IP cores, a core value part of fabless companies, is high. Hence, fabless companies can also improve their technical capabilities and earn more customers by acquiring companies with complementary technologies.

Moreover, strategic transformation is also a common approach for IDM and fabless companies in responding to competitive dynamics. IDM companies can spin off fabs to become fabless, shedding heavy asset characteristics, or operate their design and manufacturing departments independently, developing the manufacturing business into a foundry to provide services for other fabless companies, such as Intel's establishment of the Intel Foundry Service (IFS) department. Conversely, fabless companies can build their own fabs focused on a single technology or product to become IDM, better controlling the manufacturing process and avoiding capacity shortages in highly competitive situations.

SQ4: *How do the results of the interaction further influence the market performance of the business model?*

As previously discussed, strategic missteps that lead to technological stagnation can have catastrophic consequences in the capital and technology-intensive semiconductor industry. Due to technical challenges or poor yield rates, Intel's prolonged issues with its 10nm process node resulted in TSMC surpassing Intel's process technology. Concurrently, AMD's collaboration with TSMC, emphasizing efficiency, flexibility, and cost-effectiveness, enabled the earlier introduction of more advanced products, accordingly causing Intel to lose market share. This issue is symptomatic of IDM companies, which often suffer from relatively low flexibility and insufficient engagement in emerging markets, leading to significant financial losses and a decline in market share. The success of the AMD-TSMC partnership demonstrates the benefits of achieving first-mover advantage, securing market leadership, and defining future competitive trajectories. Moreover, diversifying product lines helps to avoid product homogenization, achieve VRIN qualities, and enable diversified revenue streams and sustainable competitive advantage.

During periods of economic growth in the industry, a reliable outsourcing strategy is crucial for fabless companies. Fabless companies can only capitalize on market demand windows and achieve profitability if they have assured, stable, and sufficient production capacity. IDM and foundry companies must develop detailed plans for current and future capacity utilization. These companies can achieve profitability only through high-capacity utilization. During economic downturns, all three business models must adopt varied strategies based on their resources and dynamic capabilities, including investing in process or design optimization, predicting future market trends for targeted R&D, and differentiating between existing and new products.

A stable and reliable supply chain is indispensable for all three business models, especially during significant market disruption. A secure supply chain ensures the survival of the enterprise. IDM and foundry companies heavily rely on long-term partnerships with advanced manufacturing equipment and raw material suppliers. In contrast, fabless companies depend not only on stable supplier relationships but also on the process capabilities and packaging competencies of foundries and assembly plants. Therefore, fabless companies should focus on collaborative cost reduction with suppliers, foundries, and packaging plants to achieve higher product margins. For foundries, having long-term stable clients ensures consistent capacity utilization, enhances the alignment between design and manufacturing, and achieves sustained substantial revenue. For instance, TSMC's top ten customers contribute approximately 50% of its revenue.

Strategic transformations are often undertaken after recognizing the limitations of the current business model in handling competitive dynamics. For instance, a fabless company might decide to build its own fab and transition into an IDM, or an IDM might plan to construct new fabs or expand into foundry services. Despite the high initial investment, if these strategies are well-executed, they can result in significant economies of scale and substantial returns on investment over time.

MRQ: *'What is the interplay between competitive dynamics, strategic adaptations and the market performance of IDM, fabless, and foundry business models in the semiconductor industry?'*

Based on the answers from SQ 1 to 4. In the competitive dynamics of the semiconductor industry, factors such as market supply and demand, the current phase of the industry cycle, the latest and most advanced design and process technology nodes, and supply chain stability directly influence the strategic adaptations of the three business models. Specific strategic initiatives, including but not limited to transformation, collaboration, or substantial investment in R&D, will vary according to the unique characteristics of each business model. These strategic adaptations impact the market performance of companies within each respective business model, as evidenced by changes in market share, revenue, profit margins, return on investment, and business coverages. Furthermore, these strategic initiatives have the potential to, in turn, reshape industry competitive dynamics, thereby further influencing the strategic adaptations of other firms. Concurrently, changes in market performance can feedback into and affect a company's strategic adaptations. The interplay among these three concepts of different business models is intricate, with interdependent and mutual influences among each pair.

7.4. Generalizability

This research presents a series of propositions regarding the relationships among competitive dynamics, strategic adaptations, and market performance within the semiconductor industry, focusing on the three primary business models: IDM, fabless, and foundry. The study employs a methodological triangulation approach, incorporating a literature review, comparative analysis, case studies of Intel, AMD, and TSMC, and thematic analysis of interviews with industry experts.

The use of methodological triangulation provides a comprehensive research framework. Including multiple data sources and diverse analytical methods effectively enhances the research's reliability and the conclusion's accuracy. The rigor of this methodology ensures replicability, making it applicable to other industries requiring multi-dimensional and multi-faceted research approaches, beyond the semiconductor sector.

While the study focuses on three specific companies representing different business models in the case studies at the enterprise level, the thematic analysis of interviews incorporates insights from experts from other companies across various business models. Therefore, although the propositions do not offer specific strategic adaptation recommendations, the integrated research findings underscore several key aspects relevant to the semiconductor industry as a whole. For instance, the study outlines broad strategic decisions that different business models should consider to mitigate competitive pressures or adapt strategically based on their inherent characteristics. These insights are applicable to companies operating under IDM, fabless, or foundry business models, regardless of their size, and to firms aiming to enter the semiconductor industry or transition to a different business model.

Regarding industry-level generalizability, while the research is confined to the semiconductor industry, the concepts of competitive dynamics, strategic adaptations, market performance, and business models are also relevant to other capital- and technology-intensive industries, such as pharmaceuticals, biotechnology, and advanced manufacturing. The frameworks and propositions discussed in this study regarding business model competition, strategy, and market performance are equally applicable for industries sharing commonalities with the semiconductor sector, such as cyclicality, capital and technology intensity, and market volatility. Further, the study's propositions concerning IDM business models, which require balancing design and manufacturing as well as internal production and outsourcing, can be inferred to other industries needing coordination in these areas, such as aerospace or automotive manufacturing.

7.5. Theoretical and managerial contributions

7.5.1. Theoretical contributions

This study integrates Anderson and Tushman's Cyclical Model of Technological Change, Barney's RBV, and Teece, Pisano, and Shuen's Dynamic Capabilities Framework to explore the theoretical linkages between competitive dynamics and strategic adaptations within the semiconductor industry. Subsequent thematic analysis of interviews synthesizes all analytical results; the mentioned cyclical technological evolution in the semiconductor industry aligns with the Cyclical Model of Technological Change theory, indicating that discontinuous technologies in the semiconductor industry indeed push the industry into an era of ferment. During this stage, design and process technologies within the industry compete until a dominant design emerges and is selected, followed by an era of incremental change, continuing until the next discontinuous technology appears and a new cycle begins.

For IDMs and foundries possessing advanced manufacturing capabilities, technological superiority enables them to pioneer the introduction of more advanced and reliable process nodes, thereby disrupting existing technological continuities. This disruption facilitates their emergence as the dominant design in the market, consequently shaping the trajectory of subsequent technological iterations. Similar phenomena are observed at the design level; for instance, the widespread adoption of the ARM architecture in mobile communications established it as the prevailing standard in consumer electronics. Conversely, Intel's failure to capitalize on early opportunities and its delayed development efforts resulted in significant setbacks within the mobile communications sector.

By embedding semiconductor industry technology into the Cyclical Model of Technological Change,

- This research provides empirical evidence that strengthens the theory's argument of the Cyclical Model of Technological Change.
- The findings extend the model's applicability to industries characterized by rapid technological advancement and discontinuity.
- This enhanced applicability enriches the theoretical framework and provides empirical support for innovation and competitive cycles.

Furthermore, the case studies illustrate that successful strategic adaptations to competitive dynamics leverage the RBV to achieve VRIN qualities and enhance dynamic capabilities using existing resources, thereby attaining sustainable competitive advantage. TSMC's process node technology, characterized by superior power efficiency, performance, and density, has granted the company VRIN qualities. This technological advantage has enabled TSMC to sustain a market share exceeding 50% since 2019. However, these sustainable competitive advantages could be disrupted due to the semiconductor industry's rapid iteration and technology-intensive nature. This disruption is embodied as being overtaken by other firms' radical breakthrough technologies rather than incremental optimization that typically forms VRIN qualities.

- This study indicates that while RBV and dynamic capabilities frameworks are reasonably applicable to semiconductor firms, it extends and refines these theories by suggesting that in the presence of radical technologies or significant market disruptions, the firm's sustainable competitive advantage will invariably be compromised to some degree.

This research employs the BMC method in the comparative analysis methodology. Typically, the BMC method is adopted for individual company studies. However, this research demonstrates that BMC can also yield valuable insights when used to study and compare industry business models. It provides a clear understanding of the characteristics of business models across the nine criteria covered by the BMC and identifies commonalities and differences between different business models through horizontal comparisons. Additionally, the combined use of BMC and C-STOF methods offers a comprehensive examination of business models from both external and internal perspectives.

- Preliminary insights gained from the BMC method can be validated by studying specific internal micro-operations of enterprises using the C-STOF method, thereby enhancing the overall depth and breadth of comparative analysis.

This study employs Eisenhardt's case study methodology to examine Intel, AMD, and TSMC. Initially, 18 propositions were formulated, subsequently refined to 9 propositions. The findings indicate that the case study approach is highly effective for elaborating abstract qualitative variables such as competitive dynamics and strategic adaptation, as well as for synthesizing phenomena and deriving conclusions.

- This research reinforces the utility of Eisenhardt's case study methodology in exploratory research. It extends the generalizability of this approach, demonstrating its effectiveness in investigating complex relationships involving multiple variables and in generating hypotheses, propositions, and conclusions.

7.5.2. Managerial contributions

The final propositions presented in this study contain five categories, offering valuable insights for practitioners within the semiconductor industry. Managers can make informed strategic decisions regarding development directions, investment priorities, and potential collaborations by understanding the characteristics, advantages, and disadvantages of IDM, fabless, and foundry models. The propositions summarize the competitive dynamics of the semiconductor industry and common strategic measures adopted by enterprises, along with their impact on market performance. These propositions provide guidance on critical aspects that managers should consider when responding to competitive dynamics and making strategic decisions.

Moreover, this study offers insights for companies of varying sizes and business models. For example, it suggests different strategic actions that small and large fabless companies should adopt when coordinating capacity with foundry companies. It also provides recommendations on which business models might be more suitable for firms primarily engaged in logic IC or power semiconductors. Due to industry characteristics, the propositions emphasize the importance of focusing on advanced technology and R&D. Ultimately, the propositions highlight the significance of achieving a stable supply chain and maintaining long-term customer relationships, and they identify relevant market indicators that different business models need to monitor.

7.6. Recommendations and limitations

7.6.1. Recommendations

Recommendations for IDM companies

Due to the capital-intensive and vertically integrated nature of IDM companies, which leads to relatively low flexibility, balancing cost control and investment cycles is crucial to enhance investment flexibility and keep pace with market dynamics. In terms of production and manufacturing, IDM companies need to differentiate between existing and new products and allocate resources between in-house and outsourced production. If IDM companies provide outsourcing services to other fabless companies, they need to precisely plan the capacity for internal production. Regarding R&D, IDM companies must anticipate future product markets and invest heavily in R&D to independently and rapidly advance corresponding process nodes. They need to balance innovation with cost efficiency and address yield issues. Regarding supply chain and customer relations, IDM companies should maintain strong relationships with advanced equipment manufacturers and raw material suppliers and leverage their integrated solutions to retain stable and loyal customers. Additionally, strategic transformations are needed when emergencies happen to enhance agility and mitigate financial pressure.

Recommendations for fabless companies

The lack of manufacturing capabilities means that fabless companies depend on foundry services for outsourced manufacturing, and the quality of the manufacturing process is constrained to the existing process platforms provided by foundries. Therefore, due to their weaker bargaining position, fabless companies need to consider their scale and internal resources when negotiating with foundries. They should adopt strategic measures to secure stable capacity or more advanced manufacturing processes while ensuring the coordination between design and manufacturing processes. These strategies could include outsourcing production to multiple foundries simultaneously or engaging in deep collaborative partnerships with foundries through cross-shareholding or mutual investment. In highly competitive markets, fabless companies should utilize the flexibility and cost advantages of the fabless-foundry model to shorten time-to-market and gain a first-mover advantage. Strategic acquisitions of companies with complementary technologies may also be necessary at critical moments.

Recommendations for foundries

For foundries, the primary focus on manufacturing requires forward-looking capacity planning for both current and future demands. High capacity utilization rates and yield rates are prerequisites for profitability, but it is also important to reserve emergency capacity for unforeseen needs. In collaboration with fabless companies, achieving DTCO is essential. For promising products, foundries might consider exclusive production line strategies. Once mature and relatively advanced process nodes are established, foundries can achieve scalability, forming synergies with fabless companies to reduce marginal production costs, thereby reinvesting funds into R&D again.

General recommendations

All three business models must concentrate on their human capital, as R&D outcomes fundamentally rely on high-skilled talent and workforces. Therefore, substantial investment in R&D is required to achieve advanced technologies and gain a competitive edge. Given the long chain of the semiconductor product, maintaining strong and stable relationships with upstream and downstream suppliers is crucial for all business models. In terms of product strategy, expanding business lines can achieve product heterogeneity, opening up new segments and niche markets to diversify revenue streams. Companies must stay continuously aware and sensitive to technological advancements and emerging trends in the semiconductor industry to avoid the risk of product obsolescence and technological stagnation. Additionally, a large customer base is fundamental to profitability, with long-term stable customers being valuable assets, especially for fabless companies. Finally, corporate strategy must carefully balance long-term strategic investments with short-term market performance while always preparing for major market disruptions.

7.6.2. Limitations

The scope of this study is limited to the three primary business models within the semiconductor industry: IDM, fabless, and foundry. While these models are highly representative, they do not cover all business models within the industry. For instance, IP companies specializing in semiconductor design and selling design licenses without producing their own branded products, design houses optimizing fabless designs and acting as intermediaries between fabless companies and foundries, and OSAT companies solely responsible for semiconductor packaging and testing are not included. The conclusions and propositions derived from comparative analysis, case studies, and interview thematic analysis are tailored specifically for the semiconductor industry. These insights related to business models, competitive dynamics, and strategic adaptations are only partially applicable to other high-tech industries, as different industries possess unique and specific features, limiting the generalizability of these conclusions.

Although the case studies selected Intel, AMD, and TSMC as relatively representative companies to compare IDM, fabless, and foundry business models, these companies are not qualified to completely represent their respective business models. Therefore, some of the related propositions derived from these companies may not be entirely applicable to other enterprises and should be used as practical references with some limitations.

The study does not confine its exploration of industry competitive dynamics and corporate strategic adjustments to a specific region or time frame, making the insights potentially less applicable and representative to particular regions such as the European or Asian markets. Furthermore, due to the rapid changes in the semiconductor industry, the study's findings are based on data collected up to mid-2024. Subsequent industry developments may alter the observed competitive dynamics and strategic adjustments, thereby limiting the time effectiveness of the study's propositions. Moreover, it is crucial to admit that the semiconductor industry comprises multiple product types. As also mentioned in reference (1:12), various product segments exhibit distinct business dynamics. This research primarily concentrates on logic IC semiconductors, with some attention to power semiconductors. Therefore, the findings and insights presented in this study may not comprehensively represent all semiconductor product categories.

Regarding methodology, This research involved examining companies' relevant financial metrics for market performance. Theoretically, such data should be analysed using quantitative methodologies. However, due to limitations in time and scope, this study does not incorporate a quantitative evaluation of the financial metrics influenced by competitive dynamics and strategic adaptations. The propositions proposed in this study are not testable, unlike the hypotheses. Additionally, the comparative analysis and case studies rely on secondary data sources such as company annual reports, industry publications, and financial websites. Although reliable, these sources may not fully capture all differences and the latest developments in the studied companies and business models, such as certain strategic measures that remain commercial secrets. The thematic analysis of interviews involved six semiconductor industry experts as interview samples. Although they provided valuable insights, the subjective nature of interviews can introduce bias, even if multiple experts mention the same viewpoint. The transcription and coding of interview data could also be affected by researcher error and interpretive bias.

7.6.3. Future research

This study investigates the relationship between competitive dynamics, strategic adaptation, and market performance across three primary business models in the semiconductor industry. Given the current general scope of the study and the broad nature of business models—which vary by company size, primary semiconductor products, and geographic regions—future research should address the mentioned limitations by focusing on more specific contexts.

Future research should focus on specific enterprises, such as companies of a certain scale, within a particular geographic region, or those operating in the same segment of the semiconductor supply chain. More precise insights into how competitive dynamics and strategic adaptations influence market performance in different contexts could be gained by narrowing the scope. Conducting longitudinal studies could allow for a sequential examination of changes in competitive dynamics, strategic adaptation, and market performance over time. This approach can highlight these variables' short-term and long-term interactions and impacts, providing a deeper understanding of their temporal relationships.

Incorporating quantitative analysis to measure market performance offers a more accurate method for understanding the interactions and effects of various factors. Specific and actionable propositions and insights can be derived by integrating statistical techniques. In addition, the combination of qualitative and quantitative analyses can enhance the reliability of the research, with quantitative methods mitigating potential subjective biases inherent in qualitative analysis.

Furthermore, future research should include stakeholder analysis to capture a more holistic view of the semiconductor industry. Recognizing that competitive dynamics, strategic adaptation, and market performance are jointly shaped by multiple stakeholders. This should extend beyond business models and companies to include customers, suppliers, governments, and regulatory bodies.

The semiconductor industry, being capital- and technology-intensive, is highly volatile and sensitive to geopolitical factors and economic conditions. It also has stringent supply chain requirements. Future research should explore how these external factors influence the three variables under study. The complex interplay of these multivariate influences deserves further exploration in future research.

7.7. Reflection

This study analyses the relationships among competitive dynamics, strategic adaptations, and market performance across different business models (IDM, fabless, and foundry) in the semiconductor industry. Throughout the research process, I found it necessary to integrate a wide range of interdisciplinary knowledge, primarily leveraging what I learned from the Management of Technology program, including courses such as Technology, Strategy and Entrepreneurship (TSE), Financial Management (FM), Research Method (RM), and Emerging and Breakthrough Technologies (EBT). For instance, when integrating theoretical frameworks, I recalled the RBV and the Cyclical Model of Technological Change learned in TSE. In examining companies' market performance, I applied financial metrics such as EBIT and ROI, which I studied in FM. This interdisciplinary approach not only enriched the analysis but, more importantly, allowed me to connect the knowledge framework established in theoretical courses with the methodologies learned in RM.

Formulating and refining propositions significantly trained my critical thinking and ability to synthesize various sources of information. Additionally, during the data collection and analysis processes, I gained extensive knowledge about the semiconductor industry from a business model perspective, viewing this rapidly evolving and highly competitive industry in a new light. Although I initially believed the information gathered from secondary data was comprehensive, the interview method provided additional novel and valuable insights from industry experts. The process of finding interviewees was indeed challenging, but it improved my perseverance and effective communication skills. This study also benefited from maintaining an open attitude towards constructive feedback and criticism from my supervisors, enabling continuous improvements and iterations.

Through my efforts in the research process and the assistance of semiconductor experts, I was able to dissect and articulate the seemingly complicated semiconductor industry more clearly, which was very beneficial. These experiences not only expanded my academic and professional horizons but also reinforced the importance of adaptability, continuous learning, and the pursuit of excellence in research.

8 Conclusion

This research explores the complex dynamics within the semiconductor industry, focusing on the interplay between competitive dynamics, strategic adaptations, and market performance among IDM, fabless, and foundry business models. Specifically, this study examines how these business models differentiate, interact, compete, and collaborate within a cyclical, technology and capital-intensive, highly volatile, and rapidly evolving semiconductor industry, thereby shaping their strategic approaches and overall market performance. A main research question and four sub-questions were defined at the outset. Through a triangulation methodology containing a literature review, comparative analysis, case studies, and thematic analysis of expert interviews, 22 propositions holding conclusive insights were developed, validated, and synthesized to address the research questions.

The literature review provided an overview of the semiconductor industry's development trajectory, the emergence of the three business models, and existing research on business models, industry competitive dynamics, and corporate strategic adaptations. This review identified knowledge gaps, gathered qualitative data for subsequent comparative analysis, and selected relevant case study companies. Additionally, the literature review clearly defined the concepts of competitive dynamics and strategic adaptation and elaborated their theoretical linkages using three existing theoretical frameworks.

In the comparative analysis, this study adopted the BMC and C-STOF model methods to analyze the three business models and the three case companies across four external environmental orientations: supply and resources-oriented, value-oriented, demand-oriented, and financial-oriented, and five internal factors: customer value, service, technology, organization, and finance. The analysis produced a comparative table highlighting the commonalities and differences between business models, initially proposing 14 propositions. The C-STOF model initially analyzes the case companies identified in the literature review for preliminary review. Insights from the five internal factors provided observations and then inferred to the business model level, supplementing and validating the results from the BMC method and serving as a transition to subsequent case studies.

The case study employed Eisenhardt's approach, conducting within-case and cross-case studies on the three selected companies, Intel, AMD, and TSMC, ultimately proposing 20 propositions. These propositions were later integrated and refined into 9 propositions within 2 categories: competitive dynamics and technological advancement, and strategic reorientation and diversification.

In the thematic analysis of interviews, the study established strict selection criteria for interviewees and engaged six experts from semiconductor companies representing the three business models. The insights obtained from the interviews were coded and analyzed using the qualitative analysis software ATLAS.ti. The final results from all methods were incorporated to modify and consolidate the propositions into a list of 22 propositions across 5 categories. The sub-questions were addressed sequentially by synthesizing the analysis results and the proposition list, thus forming a complete answer to the main research question.

The triangulation methodology employed in this study can be generalized and replicated in other research contexts requiring multi-dimensional approaches. The broad strategic decision-related propositions at the enterprise level can serve as valuable references for semiconductor companies across different business models. The propositions and insights related to the attributes of the semiconductor industry can be generalized and applied to other capital- and technology-intensive sectors. This study situates the semiconductor industry within the frameworks of RBV, the Dynamic Capabilities Framework, and the Cyclical Model of Technological Change, thereby strengthening and extending these theories. Additionally, by using the BMC to analyze business models, the study broadens the scope of its application. Furthermore, the study provides key recommendations for corporate managers to consider when responding to competitive dynamics and formulating strategic decisions specific to each business model and overall.

However, this study acknowledges certain limitations due to the temporal nature of secondary data, the subjectivity inherent in primary interview data, and the representativeness of case companies. Future research should focus on utilizing more detailed company data, conducting quantitative methods to measure effect, ensuring geographical generalizability, and incorporating broader influencing factors, such as geopolitical considerations. In conclusion, this study leverages existing theoretical and methodological frameworks to conduct a thorough analysis of business models, competitive dynamics, strategic adaptations, and market performance in the semiconductor industry, thereby contributing to theoretical knowledge and offering practical reference value.

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A

Appendix A. C-STOF model table

A.1. C-STOF model original table

Table A.1: C-STOF Model Analysis, Heikkilä et al. (2008)

Criteria	Sub-Criteria	Indicators
Customer Value	Value uniqueness, quality	C1. Created customer value (qualitative description): unique; new to the world; user experience; perceived customer benefit; brand image; # of referrals; attraction of media; price, product range and flexibility of product; regulation-related and non-tangible values
		C2. Market segment and market share: e.g., reach and depth of customer relations; new and repeat business; customer costs; # of countries/areas; search costs, communication; sales growth; sales volume; customer lifetime; profit/revenue per customer segment/per product; customer loyalty; average order size; opportunity size
		C3. Website-related indicators: e.g., # of hits; page views; click-throughs; # of unique visitors; # of repeat visitors; % of online sales abandoned before completion; % of customers who have personalized their interfaces; duration of stay (stickiness); registered users; conversion rate; cross-sell ratio; channel mix change
Service	Service-related	S1. Service Development life cycles: development time of new service (concepts); time to first proposal; # of customer-requested features added per upgrade
		S2. Quality: e.g., conformance to specifications, product/service performance, availability; reliability, transparency, product/service defect/failure rates, quality delivery, time between order and receipt (delivery time service), average time to respond to customer request; out-of-stock positions, on-time shipments; shipment accuracy, % of orders delivered to correct address, packaging quality
		S3. Satisfaction: e.g., service level; SERVQUAL or SERVPERF; satisfaction barometer; # of customer complaints; level of billing errors; cycle time to respond to customer complaints
		S4. Sustainability: viability, loyalty; level of customer churn; customer retention

Table A.1: (continued)

Criteria	Sub-Criteria	Indicators
Technology	Applications, Architecture, Hardware, Data Infrastructure	T1. Architectural complexity: # of applications; architecture-related indicators; platform-related indicators; cloud-related metrics, time for software and hardware implementation; extensibility
		T2. Data complexity: e.g., consolidation of databases; # of decentralized (customer) databases, data integration; data availability
		T3. Interoperability: metrics of interoperability of systems: % cross system collaboration, system and information quality metrics
		T4. Accessibility and Up-time: 24-7 availability and downtime; response time, average time to load a page, # of languages; help desk calls; disaster recovery; mean time between failures, data security/integrity
Organization (Internal and external)	(Internal and external) Organization network, Complexity, Density, Structure	O1. Number of internal partners: # of units and departments; # of organizational layers involved; # of (skilled) employees; roles and responsibilities
		O2. Access to resources: access to business network, suppliers, external and internal resources; inventory levels; capacity and expertise flexibility, quality
		O3. Number of external partners: # of Tier-1 (core network partners) Tier-2 (replaceable provider and product/service) and Tier-3 (partners included based on market availability) network partners, % cross unit/organizational collaboration
		O4. Characteristics of (internal) Network: size; inclusiveness, connectivity, density; centralization, symmetry; brand; owned versus outsourced manufacturing
Finance	Profitability, Revenues, Cost, Risk	F1. Network value: value created by core service for core provider as well as for the ecosystem, profit-related metrics
		F2. Profitability: ROl; NPV; EPS, EBIT(A), net profit, profit margin; unit margin, unit pricing, turnover, revenue (growth)(mix); return on equity, cash flow; market capitalization, share price, forecast reliability, sales backlog, project profitability, time to break even
		F3. Costs: total expenses; CAPEX; OPEX; development costs; investments in technology, marketing costs; operational costs/loss; cost efficiency; fixed cost investment; cost control
		F4. Risk: risk indicators; credit items; credit terms

B

Appendix B. Interview

B.1. Interview questions

B.1.1. General questions:

1. Can you provide a brief overview of your experience in the semiconductor industry and your current role?
2. How has your role and the focus of your work evolved over the years in the semiconductor industry?
3. From a practitioner's perspective, do you think that the main business models of the current semiconductor industry are IDM, Fabless and Foundry?
4. How do you perceive the current state of the semiconductor industry in terms of competition of these business models?

B.1.2. Business model questions:

IDM (if the interviewee is from IDM company)

1. What do you think are the main advantages and challenges of the IDM business model in the semiconductor industry?
2. How do IDM companies maintain their competitive edge using strategies under the background of rapid technological changes? (For example, Intel had invested 20 billion dollars in building two new fabs in Arizona to develop their foundry business)
3. Can you discuss any recent strategic adaptations your company has made to maintain or enhance its market position?

Fabless (if the interviewee is from Fabless company)

1. What are the main strengths and weaknesses of the fabless business model?
2. How do fabless companies manage their relationships with foundries to stay competitive?
3. How can the fabless model help your company innovate and adapt to market demands?

Foundry (if the interviewee is from Foundry company)

1. What are the critical success factors for foundry companies in your opinion?
2. How do foundries balance the demand from multiple fabless clients while maintaining operational efficiency?
3. How does your company adapt to the evolving technological requirements of fabless partners?

B.1.3. Competitive dynamics questions:

1. How do companies in the semiconductor industry typically respond to competitive pressures?
2. How does technological innovation influence competitive dynamics in the semiconductor industry?
3. Can you provide examples of how competitive dynamics have shaped strategic decisions in your company?

B.1.4. Strategic adaptations questions:

1. How do companies in the semiconductor industry adapt their strategies to market shifts and disruptions? Could you provide examples of both successful and unsuccessful adaptations?
2. What role does strategic foresight play in these adaptations?
   Follow-up question: How can strategic foresight be integrated into a company's daily operations?
3. Based on your experience, can you share a specific example of a company or your company in the strategic adaptations that have shaped the competitive dynamics in turn?

B.1.5. Market performance questions:

1. What are the most critical metrics for evaluating the market performance of semiconductor companies, and how do they differ across IDM, fabless, and foundry business models?
2. How do you measure the impact of strategic adaptations on your company's market performance? Could you provide specific metrics and examples of how these impacts are measured?

B.2. Interview quotations

B.2.1. Interviewee 1

Table B.1: Interview quotations and codes from interviewee 1

ATLAS.ti reference	Quotation	Code
(1:1)	Its advantage is that all R&D, manufacturing, and testing are done internally, so it is easy to integrate resources and coordinate to make it more efficient, so that it can quickly respond to customer needs, and continuously improve production efficiency and reduce costs.	IDM advantages
(1:2)	The disadvantage is that it is a production model with heavy asset investment. When you expand production, you need to invest a lot of money in the early stage.	IDM disadvantages
(1:3)	The advantage is that it does not need to invest a lot in fixed assets. Its main investment is in people. Finding the right foundry and the right assembly plant will bring good financial returns.	Fabless advantages
(1:4)	It cannot control production on its own. If there is a shortage in the market, its cost will rise sharply, and it will face the problem of how to get enough production capacity and how to control costs to get the right production capacity.	Fabless disadvantages
(1:5)	The second disadvantage is that it is difficult to find its core competitiveness in the process of manufacturing. It can only optimize the design link, but in the process, it will rely on the capabilities of foundry and assembly.	Fabless disadvantages
(1:6)	It can get a lot of synergy in its foundry to reduce costs, and then after a certain amount of initial investment and recovering the return on investment, it will be able to compete with other competitors with a great cost advantage in the later stage. At the same time, it can continuously update and iterate in terms of technology.	Foundry advantages
(1:7)	This assembly factory, while controlling costs, has the advantage of cooperating with Fabless. Fabless has no funds to invest, but it has funds to invest and has sufficient production capacity to help Fabless to do some new designs and new optimizations.	Foundry advantages

Table B.1: Interview quotations and codes from interviewee 1 (continued)

ATLAS.ti reference	Quotation	Code
(1:8)	Its disadvantage is that it needs to invest a lot in the early stage. Later, when it starts to make money, there may be no market for this product, which is a big risk, so it must find the right product.	Foundry disadvantages
(1:9)	It must be foresighted to judge whether it can make money in ten years.	Foundry disadvantages
(1:10)	The derivative version of IDM is part IDM and part fabless.	IDM strategies
(1:12)	Semiconductors also have many products, and different segments of this product have different formats.	Industry features
(1:13)	There is no shortage of design houses or fabless in the market now. When the production capacity is insufficient, everyone is scrambling for production capacity, so what he needs more is to find a partner to give him a fixed amount.	Fabless disadvantages
(1:14)	One of the things that the wafer factory needs to plan is the technology node and the future market demand for the product.	Foundry strategies
(1:15)	The semiconductor industry is a cyclical industry. When the market is very good, the competition is very fierce. The reason for this competition is that the demand of the final customers is very strong.	Industry features
(1:16)	The sales pressure is relatively small. Their pressure comes from how to ensure production. Then he has to ensure that his upstream supply chain has enough supply to support my production.	Industry features
(1:17)	If a new concept comes out, it will affect the whole situation. For example, the electric car a few years ago changed the whole industry.	Competitive dynamics influence strategic adaptations
(1:18)	At that time, our company did the opposite, that is, it judged that the epidemic would recover, but we didn't know when the epidemic would recover, and it also depended on the company's cash flow.	IDM strategies
(1:19)	Our long-term strategic planning is three to five years or even longer. What kind of products and roadmap should we focus on? But at the same time, we will have a strategic discussion every year.	IDM strategies
(1:20)	I think many indicators will be concerned, because we look at the ranking of semiconductor companies. The first is revenue size, the second is market share. The third is EBITA. The sales of some of the top semiconductor companies, Intel, TI, Infineon, must be very large.	IDM market metrics
(1:21)	Fabless is more about profit and sales.	Fabless market metrics
(1:22)	Foundry is more about cost, because it is a heavy asset for production and manufacturing. It is difficult to measure it with a margin, but this margin must be positive. The higher the margin, the better.	Foundry market metrics
(1:27)	IDM lives longer because it keeps many core advanced things in its own internal, and many things they can copy from the outside are low-profit and low-threshold things.	IDM advantages

Table B.1: Interview quotations and codes from interviewee 1 (continued)

ATLAS.ti reference	Quotation	Code
(1:28)	Our main strategy is to reduce costs, because it is relatively mature. For all our products, I want to make them produce at a lower cost, produce more products, and then sell more to customers. This is an existing product. New products, the new product is to open up the market and you want to get more market share, then you can't do the old product to increase the margin and increase the sales.	IDM strategies

B.2.2. Interviewee 2

Table B.2: Interview quotations and codes from interviewee 2

ATLAS.ti reference	Quotation	Code
(2:1)	I think its disadvantage is more important at the commercial level, because it is heavily dependent on suppliers. If the supplier has a bad relationship with Fabless, or if he has a bigger customer, he may cut your order. It is equivalent to your supply chain being risky.	Fabless disadvantages
(2:2)	The end user hopes that the companies that their suppliers supply him with devices have their own production capabilities, at least you have to ensure that the part he uses is low-risk.	Fabless disadvantages
(2:3)	Strategic cooperation means to make a deep bond with the foundry. If a promising company really wants to make long-term plans for itself, it may have to make a deep bond with the foundry in other ways besides placing orders, such as cross-holding or mutual investment.	Fabless strategies
(2:4)	Large companies are actually platform-based. They will not specifically target a certain scenario or application, even if the volume may be large, and the possibility of them developing a chip for this scenario is very small.	Fabless strategies
(2:5)	In the early years, IDM had a lot of accumulated customers, and these customers had user habits. They may feel that although the indicators are not good enough, they are enough for them to use.	IDM advantages
(2:7)	I think the world is the same, that is, it actually depends on innovation and development, and only by innovation can make things better than others.	Competitive dynamics
(2:9)	The characteristics of the semiconductor industry are long R&D cycles, and the R&D cycle is very long. It takes a long time to verify it from the development to the actual use of the terminal, especially for application scenarios such as electric vehicles or data centres, which have high requirements for reliability. Therefore, I think it is very difficult without strategic vision.	Industry features
(2:14)	Design companies need to have a suitable market, which is similar to a niche market, and focus on this field alone.	Fabless market metrics

Table B.2: Interview quotations and codes from interviewee 2 (continued)

ATLAS.ti reference	Quotation	Code
(2:16)	The wafer factory must consider the capacity utilization rate. For example, you can make money when the capacity is full or even 80%. If you can't achieve this, you will be in a loss state, so the capacity utilization rate is a very important indicator.	Foundry market metrics

B.2.3. Interviewee 3

Table B.3: Interview quotations and codes from interviewee 3

Reference	Quotation	Code
(3:1)	The advantage of fabless is that it is asset-light, which means it does not have to bear too many asset burdens, especially when the industry is not very prosperous.	Fabless advantages
(3:4)	Basically, fabless can only design its products for the existing open platform of the foundry, so this product may be relatively normal, and the competitor's products may be similar to its own, because the platform and process norm are basically the same.	Fabless disadvantages
(3:5)	It is necessary to see whether the cooperation with this Fabless is strategic. If it is a key customer of the fab, it may be able to get some production capacity guarantees and production capacity support, and the price support is even more unnecessary.	Fabless disadvantages
(3:6)	Why should I build my own fab? That is because we currently have no way to produce some products with our own process characteristics, and it is possible that today's process is different from tomorrow's process. If the design company only asks the wafer factory to do the foundry, then the cooperation with the wafer factory will definitely not be so good.	Fabless strategies
(3:7)	For example, if the original quotation for a wafer is 500 US dollars, then if the market is good and the competition is fierce, then fabless will ask if it can give more production capacity, such as purchasing at a price of 530 or 550.	Fabless strategies
(3:8)	In addition to having this product in this fab, I also have this product in another fab. If the price or production capacity does not support me, I will transfer part of it to another fab.	Fabless strategies
(3:9)	The current so-called IDM and Fabless are not so strictly defined. A fab wafer factory can also be operated by an independent project company, and it is also responsible for its own profits and losses.	Fabless strategies, Industry features
(3:10)	Infineon actually has a lot of them. This wafer is outsourced to Samsung, just the power device IGBT. Under the condition of tight production capacity, it should have more than half of these power devices outsourced to others, and it is also producing them in its own wafer factory.	IDM strategies
(3:12)	It is possible that a new special process will suddenly emerge, and everyone may basically start from the same starting line, so everyone can do this new process and build a new fab.	IDM strategies

Table B.3: Interview quotations and codes from interviewee 3 (continued)

Reference	Quotation	Code
(3:15)	The second point is to expand the application scenarios of this product. It is equivalent to developing some niche areas. It is possible that the volume will not be too large, but the market competition may not be so fierce.	IDM strategies
(3:16)	For example, for products with fierce competition, if we originally launched them according to the planned nodes, then it is very likely that we will suspend the project. Otherwise, for example, can we use the next generation of products in advance to adapt to the latest market?	Competitive dynamics influence strategic adaptations
(3:17)	We will see if there are some new application scenarios, and then we will make the whole solution, because there are many customers who do not have such a solution development team, especially small and medium-sized customers, so we will develop some solutions that are more suitable for their scenarios for such small and medium-sized applications.	IDM advantages
(3:19)	We reviewed that except for some very special products, which are relatively large in quantity, we must produce them in at least two fabs, which is equivalent to saying that I will not be affected too much in the case of tight production capacity.	Strategic adaptations, Competitive dynamics influence strategic adaptations
(3:20)	IDM will definitely evaluate its production capacity processing rate and its profit index.	IDM market metrics
(3:21)	As for Fabless, I personally think that it depends on whether the company's products are competitive. Then the second is the back-end operation management, which is the control ability, because it does not have a fab.	Fabless market metrics
(3:25)	I think in the next two to three years, many IDMs will go out of business and will have to sell their fabs. In fact, some of our competitors are also IDMs. Firstly, it is very likely that they have estimated the market too well. As a result, they have spread their business too wide, or their technical accumulation is not enough, and their team cannot support it, so they may not be able to continue.	Fabless advantages, IDM disadvantages, Market trends

B.2.4. Interviewee 4

Table B.4: Interview quotations and codes from interviewee 4

Reference	Quotation	Code
(4:1)	Why do IDM and foundry exist? In fact, the driving factor behind them is cost.	Industry features
(4:2)	Foundry can discuss with fabless whether fabless can modify the design to make the design more friendly to the process under the current process limit.	Foundry strategies
(4:3)	The ultimate reason for the emergence of IDM is that there is a contradiction between the design and the process. Sometimes the growth rate of the design is too fast and the process can't keep up. So at this time, the process design needs to develop in coordination.	IDM features

Table B.4: Interview quotations and codes from interviewee 4 (continued)

Reference	Quotation	Code
(4:5)	The design of devices in the field of special processes is a very critical technical point in itself, and this critical technical point cannot be known by a third party.	IDM strategies
(4:9)	In fact, the foundry is relatively strong for small fabless companies, because it cannot develop an independent process for every small customer. This is impossible. It will develop a process platform and hope to be compatible with more such requirements.	Foundry advantages
(4:10)	Why foundry can achieve such a good capacity planning depends on the fact that the semiconductor process is broken down into more than 1,000 complex processes. After one process is completed, more capacity can naturally be arranged.	Foundry features
(4:11)	The operation of fab is completely dependent on orders, because fab operates 24 hours a day. If its machine is idle for one hour, it is equivalent to continuous depreciation. In addition, its clean room is constantly operating, and its daily consumption cost is very high. Therefore, fab must keep a basically flat or profitable state, and the entire line must be kept running.	Foundry features
(4:12)	The current foundry has absorbed the previous experience, that is, it is not completely dominated by large customers. For example, 80% of the production capacity is given priority to large customers, and 15% of the production capacity must be reserved for some small companies with room for development, and 5% of the production capacity is used for emergency reserves.	Foundry strategies
(4:14)	In the early game between fabless and foundry, small fabless companies must be on the weak side.	Fabless disadvantages
(4:15)	However, for small fabless companies, they could not choose two foundries for production in the early stage, because the products produced by the two fabs need to be verified by the second source, and the verification cycle is very long, at least two years.	Fabless strategies
(4:16)	At present, the competitive pressure between semiconductor companies mainly comes from several aspects. One is the market side, that is, your product must have a certain share in the market.	Competitive dynamics
(4:17)	The price reduction space of fabless finished products can only be compressed from the supplier side, which will further exploit the chip suppliers and material suppliers. Everyone will work together to reduce the cost, and it will eventually be shared by all my suppliers.	Competitive dynamics influences strategic adaptations
(4:20)	The ups and downs of the entire industry, when the entire semiconductor production capacity is saturated, but there is no new generation of products, it will slowly enter a saturated downward range. Of course, this range is not entirely determined by the supply relationship, but also involves the political structure of the entire world.	Industry features
(4:25)	Fabless must pay attention to the strategic layout of the next generation or even the next generation of the next generation of products.	Fabless strategies
(4:26)	The current market evaluation of foundry depends on its revenue, that is, what is the capacity of this fab? The market will use this indicator to evaluate whether the foundry is healthy.	Foundry market metrics

Table B.4: Interview quotations and codes from interviewee 4 (continued)

Reference	Quotation	Code
(4:28)	Because the final process is to serve the product, if the application of your product is too narrow, it is actually equivalent to a narrow process.	IDM strategies
(4:30)	The IDM model is better for the field of special processes.	IDM strategies

B.2.5. Interviewee 5

Table B.5: Interview quotations and codes from interviewee 5

Reference	Quotation	Code
(5:1)	Fabless is a model with high IP density. Its design is to generate the value of the semiconductor. The IDM model is not mainly about the value generated by design, but mainly about the value generated by stable and reliable production.	Fabless features, IDM features
(5:2)	Companies with high intellectual property rights, such as Nvidia and AMD, will adopt this fabless design model and then find a better foundry. This foundry mainly improves its process technology support.	Competitive dynamics, Fabless features, Foundry features
(5:4)	IDM will relatively have a cost control problem. Cost control means the investment cycle and feedback. If you invest too early or too late, it is not in line with the rhythm of the listing market.	IDM disadvantages
(5:5)	For IDMs like Intel, I feel that production and design should be separated. In this way, the risk of the entire enterprise operation can be relatively reduced. If your advanced process is not achieved, at least you can produce chips in other fabs and design more optimized chips.	IDM advantages, IDM strategies
(5:6)	Power semiconductors must go the IDM model, because design can not add any intellectual property rights. Ultimately, all intellectual property rights are in this process production process.	IDM strategies
(5:7)	The biggest difficulty in semiconductors is whether the factory can be fully operational. If it is not fully operational, a lot of money will be lost. If it is fully operational, it can avoid losses and even make a lot of money. Assuming that the utilization rate is below 60%, it will lose money, and above 60%, it will make money. So this situation is a comparison between investment and market trends.	IDM strategies
(5:8)	The cycle of power semiconductors is relatively long, because it completely requires the reliability of the process to support it. For power semiconductors, it may take 3-5 years to produce a generation, which is already very good.	Industry features
(5:10)	For example, Infineon has a relatively successful strategic transformation. At the beginning, Infineon was making communication chips. It found that the iteration cycle could not catch up with Samsung, so it gave up this aspect and turned to focus on power semiconductors with a longer iteration cycle.	IDM strategies, Competitive dynamics influence strategic adaptations

Table B.5: Interview quotations and codes from interviewee 5 (continued)

Reference	Quotation	Code
(5:15)	Power semiconductors can achieve more reliability and can be made into an IDM model. It is necessary to master the most core technology part internally. In this way, when the market is not good, the money can be used to upgrade the production line and develop the production line process. When the market is good, because it has its own fab, it can have a relatively flexible price.	IDM strategies
(5:17)	If it is a long-term and stable customer, such as Bosch, some things will be produced at Infineon, but it only produces on one production line of Infineon and buys part of the production capacity, which can only be used for production for Bosch.	IDM features

B.2.6. Interviewee 6

Table B.6: Interview quotations and codes from interviewee 6

Reference	Quotation	Code
(6:1)	At present, the competition among these three business models in the semiconductor industry is very fierce. IDM companies need to maintain their leading position in technology and manufacturing capabilities, while also facing huge capital investment pressure. Fabless companies need to continue to innovate to meet the rapidly changing market needs while managing their relationship with foundries. Foundry companies need to continuously improve their manufacturing processes and maintain efficient production capacity to meet the needs of multiple customers.	Industry features, IDM features, Fabless features, Foundry features
(6:4)	In our company, competitive dynamics have a great impact on strategic decisions. For example, in the face of the growing demand for high power density and high reliability of new energy vehicles, we decided to increase our R&D investment in power electronic packaging technology and launched a series of advanced packaging solutions. It helped us improve product performance and enhance market competitiveness and share. Such strategic decisions are based on in-depth analysis and understanding of competitive dynamics.	Competitive dynamics influence strategic adaptations
(6:6)	Companies under different models focus on different indicators: In the IDM model, revenue growth rate and market share are more important. Gross profit margin is also important, reflecting cost control and production efficiency. Fabless companies pay more attention to the proportion of R&D investment and innovation capabilities, because these directly affect the competitiveness of their products. Foundries mainly focus on capacity utilization and production efficiency, because these indicators directly affect their profitability.	IDM market metrics, Fabless market metrics, Foundry market metrics
(6:8)	This is the front-end division, and there are also OSATs (open-package and test plants) in the back-end. The IDM model integrates all links such as design, manufacturing, and open-package and test. The fabless model focuses on design and sales, outsourcing manufacturing to foundries, while foundries focus on manufacturing and provide services to multiple fabless companies.	Industry features