Smart Contract Mechanism in Semiconductor Procurement System

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The pivotal role of semiconductors in propelling the rapid advancement of technologies, such as artificial intelligence, electric vehicles, and robotics, has prompted global attention toward bolstering semiconductor competitiveness. A fabless firm's performance is a determinant factor in this landscape. However, the dominance of established global fabless firms in the semiconductor market presents formidable barriers to the ingress and expansion of new entrants. Consequently, this study advocates for a novel semiconductor business model utilizing smart contracts based on emerging blockchain technology. To substantiate the efficacy of this model, a survey encompassed 106 semiconductor experts across 11 nations. Results indicated that 75% of respondents perceived an enhancement in fabless growth of the semiconductor business model. They affirmed the potential for acquiring new clientele, thereby highlighting the significance of this business model in furnishing a novel growth trajectory for fabless semiconductor companies seeking entry into the global market.

Keywords: Blockchain, Fabless Semiconductor firm, Smart contract, Semiconductor industry, Business Model.

1. Introduction

Semiconductors are one of the elements that significantly change our daily lives. The semiconductor industry's growth can lead to overall economic growth and revitalization, bringing many changes to current and future lifestyles [1]. Since the invention of the semiconductor at Bell Laboratories in the United States in 1947, the IDM(Integrated Device Manufacturing) model, in which one company conducts everything from design to manufacturing, has played a leading role in semiconductor development [2]. The IDM model refers to a model in which semiconductor companies proceed vertically from design to packaging. Examples of such companies include Intel, IBM, and Texas Instruments in the United States. However, in the early 1980s, a semiconductor business model that separated

the industry's design and manufacturing processes emerged.

A company that specializes only in semiconductor design is called Fabless such as Qualcomm, nVidia, AMD in the United States and a company that only specializes in manufacturing is called Foundry such as TSMC, UMC in Taiwan [3]. The fabless semiconductor business grows through early customer acquisition. In particular, although new fabless companies possess competitive technologies, Set manufacturers tend to avoid applying them because they lack mass production experience and low awareness. Even if new fabless companies produce competitive semiconductors in this industrial environment, actual Set manufacturers are reluctant to mass produce them, making it more challenging for new companies to enter the global market and expand their business [4].

Semiconductor design has become more complex and diversified over time, requiring large development costs. Such high development costs are a huge burden for fabless companies to develop new products. In addition, even if a huge development cost is used, a close collaborative relationship with Set manufacturers is necessary for actual commercialization, but there are not many Set manufacturers willing to propose collaboration with new fabless companies. Thus, Set manufacturers prefer to use fabless semiconductors with a history of mass production to efficiently apply increasingly complex semiconductors. In this business environment, it is increasingly difficult for new fabless companies to create business opportunities with Set manufacturers [4].

This paper proposes a new semiconductor business model with Smart contracts-based blockchain to secure opportunities and growth for global fabless companies. To prove the effectiveness of the new business model, we conducted a research survey with 106 people in 11 countries around the world. The rest of the article is organized around the following topics: In Chapter 2, we analyze the classification of semiconductor companies, the market share of each fabless company, and the concepts of blockchain and smart contracts. Chapter 3 shows the concept of a smart contract-based blockchain semiconductor business model. The differences between the new and existing semiconductor business models were also explained. Chapter 4 summarizes the survey results on the new business model and proof of the model's effectiveness. Chapter 5 presents the conclusion and implications.

1.1 Research Background

The semiconductor manufacturing process is one of the products in many industries that requires the most thorough and well-established global supply chain cooperation system [5]. Such semiconductor components implement the core performance of all electronic devices. For example, it is widely used in all industries, including smartphones, automatic controls, automobiles, consumer goods, and communication equipment. As applications expand, the semiconductor industry grows, reaching $600 Billion in 2022. Semiconductor manufacturing is divided into three stages: “design, manufacturing, and packaging,” each step requires high technical skills [5].

Among semiconductor companies, fabless companies specialize only in semiconductor design. Since the semiconductor manufacturing process requires enormous investment and maintenance costs, foundry companies use this corporate model. Fabrication is a compound

word of 'Fabrication' and 'Less' and refers to a semiconductor manufacturing facility. It appeared in the United States in the 1980s, and representative companies include Qualcomm and Broadcom [5].

Tab. 1 Semiconductor Company types Market Share by Regions(IC Insights 2022)

Share %	U.S	Korea	Taiwan	Europe	Japan	China
IDM	47	33	3	9	8	0
Fabless	68	1	21	0	0	4
Total	54	22	9	6	5	4

As shown in Tab. 1, semiconductor companies are divided into IDM and Fabless. The United States and Taiwan lead most fabless companies, and there are many limitations for new fabless companies in other countries to grow their businesses successfully.

The global semiconductor market is led by several countries and regions. Traditionally, the IDM semiconductor market and the fabless semiconductor market is led by United Sates companies. Overall, the United States accounted for 54% of the global semiconductor market in 2021, followed by South Korean with a 22% share. Taiwanese accounted for 9% of total semiconductor sales thanks to the semiconductor sales of fabless companies, which is higher than that of European and Japanese 2022 China accounted for only 4% of the global IC market. Japan led the memory semiconductor field with a 49% share of the worldwide semiconductor market in 1990, but its share fell to 5% over the next 30 years. European companies have maintained a steady 9% of the worldwide market over the past 100 years, but the situation has deteriorated to 6% since 2005. South Korean and Japanese companies are fragile in the fabless semiconductor sector, while Taiwanese and Chinese companies have a meager IDM share of the semiconductor market [6].

Tab. 2 Fabless Semiconductor Market Share Ranking (Trend force 2022)

2022	2013	Fabless	Head quarter	2022	2013
Rank	Rank			Market Share,%	Market Share,%
1	1	Qualcomm	U.S	27	27
2	2	Broadcom	U.S	19	13
3	5	nVidia	U.S	16	6
4	3	AMD	U.S	15	8
5	4	MediaTek	Taiwan	13	7
6	6	Marvell	U.S	4	5
7	16	Realtek	Taiwan	3	2
8	11	Novatek	Taiwan	2	2
9	19	Cirrus Logic	U.S	1	1
10	-	Will Semi.	China	1	-

Tab. 2 shows that compares the sales rankings of fabless semiconductor design companies around the world in 2013 and 2022, respectively. When comparing the market share rankings of fabless companies from 1st to 6th, they are the same with no change in 2013 and 2022. These results show that existing leading companies are gaining stronger market share. In other words, it shows that it is difficult for a new fabless company to enter the market and grow into a top 5 company. Review the changes in the sales rankings of fabless semiconductor companies over the past ten years; United States fabless companies such as

Qualcomm, Broadcom, nVidia, and AMD occupy 1st to 4th place, while Taiwan's MediaTek ranks 5th. The rankings of companies from 1st to 3rd place are the same, and those up to 6th place are the same as ten years ago [7]. This fabless rank shows that when latecomers or new companies enter the fabless semiconductor market, securing new business opportunities and expanding successful business is challenging. This explains that it is difficult for new fabless companies to reach the top rankings even when comparing ten years ago and now. It also shows that the competitiveness of countries and companies leading the existing market continues [8].

Even if these latecomers enter the semiconductor field, their country's semiconductor human resources and manufacturing infrastructure must catch up to those of advanced countries. In such a situation, it is becoming more difficult for latecomers or countries to succeed in the semiconductor business [9]. Latecomers must approach the necessary aspects of the company and environment through diverse approaches and strategic collaboration. For fabless companies to develop semiconductors, it takes a lot of development cost and time to optimize complex performance. For that reason, there are many barriers for new fabless companies to successfully enter the market. [9].

1.2 Literature Review

1.2.1 Fabless Semiconductor Industry

According to previous research, the fabless semiconductor industry took a lot of work for latecomers or emerging fabless firms to enter the new market. Latecomers in emerging fabless firms were found to be 'latecomers with insufficient resources. “Lack of resources” means that latecomer have many limitations and shortage in using various items. Such as technology, human resources, government support and industry infrastructures etc. This difference widens over time, and latecomer companies or companies from developing countries find it difficult to enter new markets [10].

Previous research on the development and limitation of the fabless semiconductor industry was conducted on marketing capabilities, government policies, CEO capabilities and human resources [11]. From a sales and marketing perspective of fabless firms, most of them are focused on their own domestic industries [12]. From a government policy perspective, policies were prepared focusing on global companies with domestic semiconductor competitiveness. Additionally, the fabless semiconductor industry needs to train more experts and produce more manpower from schools [12]. In order to achieve successful results in the fabless semiconductor business, people who establish start-up and have experienced innovative work at previous companies are more likely to perform innovative work [12]. From a CEO perspective, most fabless CEOs aim to list their companies on the stock market to expand their businesses. Even after listing on the stock market, a plan is needed to enter the global market, but this is a weak point and there are limits to continuous growth [13].

In the global semiconductor market, most fabless companies are small and medium-sized companies, and there are many barriers to entry into leading companies within the top 10 in sales [14]. In order for fabless companies to develop, stabilization and diversification of the

semiconductor ecosystem are necessary, and a technological strategy is needed to find new customer demand in various application groups and strengthen R&D for each application group [15]. For example, countries with developed smartphones, white goods, and automobile industries also have fabless companies specializing in related applications. In Japan, fabless companies specialize in applications such as cameras, game consoles, and automobiles. In Europe, fabless companies are working on automotive applications. In Korea, fabless companies specialize in smartphones, automobiles, and white goods [16].

1.2.2 Blockchain and Smart Contract

Blockchain was first conceptualized by Satoshi Nakamoto in 2008 and later materialized into the digital crypto currency as Bitcoin [17]. Blockchain is a decentralized database that stores continuously growing data through chains on a network [17]. It is a technology that records and manages transaction records on a block (node) basis by distributing the authority for transaction recording and management to a P2P network composed of participants (peers) [17]. In figure 2 shows that this is not a centralized network, but a new system of decentralized networks. All transactions are stored in participating blocks (nodes) and managed by each participant (peer), enabling mutual reliability verification, and authentication, recording, and auditing of all transaction records. This part is called the public transaction ledger or ledger [17].

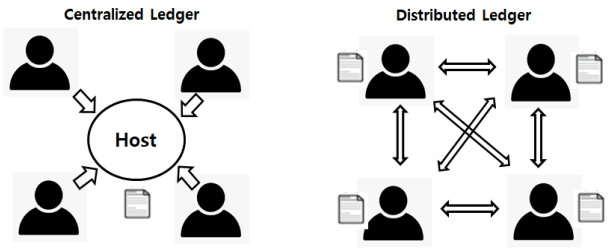

Figure 1 Centralized Ledger versus Distributed Ledger

The blockchain is a vast open network divided into a public blockchain that anyone can participate in the network and a permission blockchain that requires permission to participate in the network [18]. The permission blockchain classifies into a private blockchain operated within the same organization by a single firm and a consortium blockchain jointly operated by several trusted participating firms that meet the participation conditions [19].

It could be done through smart contracts and digital commands that operate the blockchain, and there has yet to be a unified definition of smart contracts. Regarding various definitions of smart contracts, in the term of first conception founded by Nick Szabo (1997), who defined smart contracts as "a computerized protocol that executes the terms of a contract" [20]. Traditional contracts are written in writing, and to fulfil the contract's terms, a natural person has to perform the contract. However, a smart contract written as a digital command can automatically execute the contents according to the program-coded conditions [20].

1.2.3 Semiconductor Industry in Blockchain

Blockchain technology and smart contracts have proven the capable of creating and empowering self-sustained business models that can withstand supply chain uncertainties and environmental adversities [21]. Smart contracts have been proven to create and strengthen business models that can build sTab. supply chains and prevent environmental problems in business [21]. These technologies can improve the safety of digital supply chains and expand the platform's reach to various applications [22]. With the distribution of counterfeit semiconductors intensifying, a solution to prevent duplication was proposed using blockchain to generate a unique hash value during the production process, making duplication impossible [22].

In order to improve the production efficiency of the semiconductor manufacturing line, a study was presented to prevent the same mistake in advance by sharing real-time defect history through blockchain [22]. As a digital improvement work to increase the efficiency of using hundreds of robots in the semiconductor manufacturing process facility, a study was conducted to increase the utilization of virtual fabrication facility facilities using blockchain [23]. Blockchain research in the semiconductor industry is mainly applied to preventing semiconductor duplication and sharing improvements to reduce defect rates in production lines.

2. RESEARCH MODEL

2.1 Model flow chart

In most semiconductor component selection processes in the semiconductor industry, fabless obtains business opportunities by demonstrating the superiority of its products through the purchasing, research, and development departments of the set manufacturing division. You will receive new semiconductor business opportunities if you receive approval from two teams. However, most set manufacturers are developing new products through collaboration with existing fabless partners. For Fabless to gain new business opportunities, it must receive approval from the purchasing department and research and development department. Still, if set manufacturers do not look for new fabless business opportunities for various reasons, it isn't easy to receive them.

A fabless company must go through many verification steps to reach the mass production stage. However, due to labor shortages, set manufacturers have limited opportunities to provide new fabless products. If this situation continues, obtaining new business opportunities won't be easy. Therefore, in this study, we propose a new business model called F-SBM (Fabless-Smart Contract-based Blockchain Model) to create opportunities for new fabless to receive business feasibilities. Figure5 show that the business flow chart compares the traditional semiconductor application process and a new business application model called F-SBM. The F-SBM business platform presents a smart contract-based blockchain flow chart.

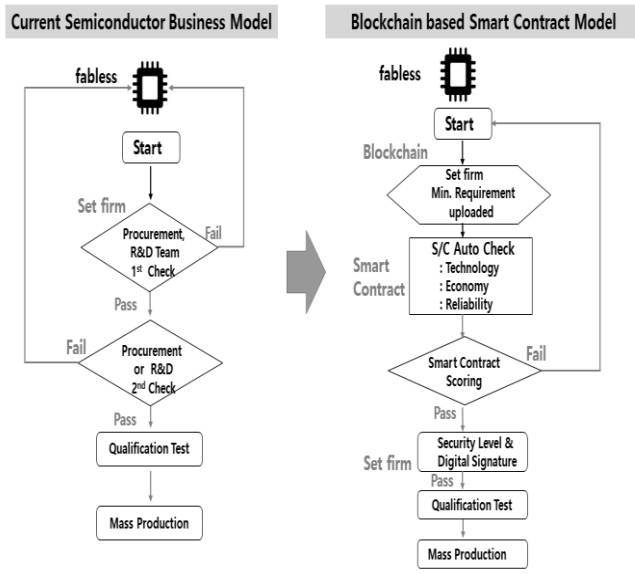

Figure 2 Comparison Semiconductor Business Model

Depending on the purpose of use, the blockchain is classified as a public blockchain where anyone can become a transaction prove, a consortium blockchain where transactions are made only by pre-agreed rules and traders, and a private blockchain accessible only to authorized users [24]. Security is emphasized so that only authorized participants can access the blockchain and cannot view unrelated contract details. In the consortium blockchain, blocks are automatically created when the rules within the consortium are satisfied, and anyone can participate if they meet the block operating conditions [25]. A smart contract is a code realized based on a block chain and guarantees that the contents of the contract are automatically executed when pre-determined conditions are satisfied [26].

Although many fabless companies around the world have competitive products, their business expansion is often restricted due to the limited domestic set application industry and limitations in power generation and human networks. As technology develops, semiconductor functions become more complex, and semiconductors require increasingly smaller sizes. Also, semiconductor functions become more complex, and semiconductors require increasingly smaller sizes. Even for Set manufactures, it is

not easy to find out a fabless firm to get a competitive semiconductor. At the set manufacture's perspective, they always try to set up a cooperation system in terms of technology, price, and quality by collaborating with at least 3 to 4 competitive fabless firms. However, due to limited manpower and short development period, it is difficult to secure competitive semiconductor components.

2.2 Model Configuration

This study aims to research the development potential of the fabless semiconductor business through the new transaction model for applying blockchain technology. This consortium

blockchain concept allows Global fabless semiconductor firms lacking human resources or funds to break away from the traditional business structure of specific application fields in their country and be allowed to enter new businesses with set manufacturers in various application groups. For example, fabless companies can create new business opportunities in various markets such as automobiles, smartphones, and AI (artificial intelligence)-based servers for agri-based food products, animal monitoring products in order to enter new markets for applications with weak domestic infrastructure [27], [28], [29]. Semiconductors are important components that determine the performance of a set maker, so which semiconductors are used is an important matter for corporate security to be maintained.

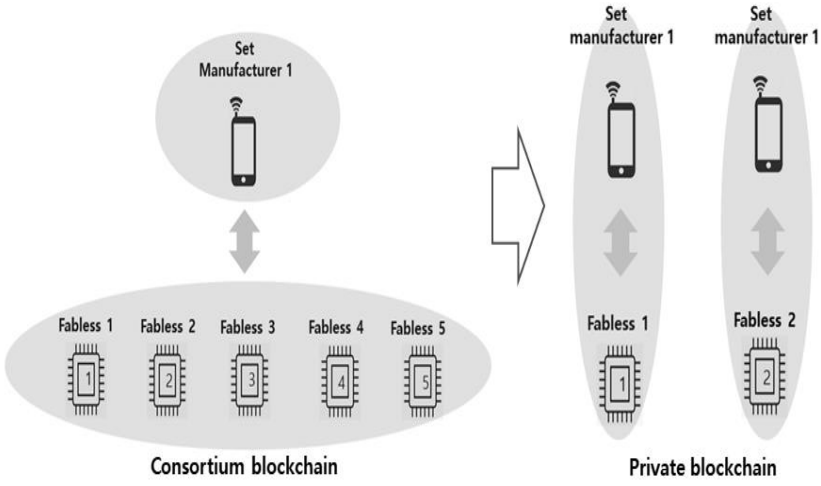

Figure 3 Consortium Blockchain convert Private Blockchain

Figure 3 explains the blockchain-based business model between fabless companies and set manufactures. In the initial product development stage, a consortium blockchain based on smart contracts is formed to create a competitive fabless pool. Set manufactures such as smartphones, laptops, servers, and automobiles allow only those companies that pass the standards required by each company through smart contracts to register in the Pool. When the smart contract presented by the set maker is satisfied in the consortium blockchain model, competitive new fabless semiconductor companies form a pool in each application group and are given the new opportunity to do with the set manufacturer.

In second stage, since maintaining security is important for semiconductor development with companies registered in the fabless pool and set manufactures, detailed development plans are discussed by converting to a private blockchain that allows 1:1 consultation. Set manufactures for each application group can individually negotiate product development with fabless companies by converting to a private blockchain format to develop semiconductors that meet their individual requirements. In a private blockchain, fabless and set manufactures can collaborate on development, so the prevention of corporate information leakage and maintenance can be strengthened compared to a consortium blockchain.

2.3 Model Workflow

Electronics set firms built a cooperative relationship with a dedicated fabless partner. In addition, set firms can improve their system competitiveness by receiving high-performance semiconductors and providing opportunities to all firms to secure competitive semiconductors. Set firms want to engage competitive new fabless firms, but there are many limitations in human resources and verification methods. They are always concerned about how to maintain the security of semiconductor information. This study suggests the workflow of the F-SBM model proposed with Figure 6.

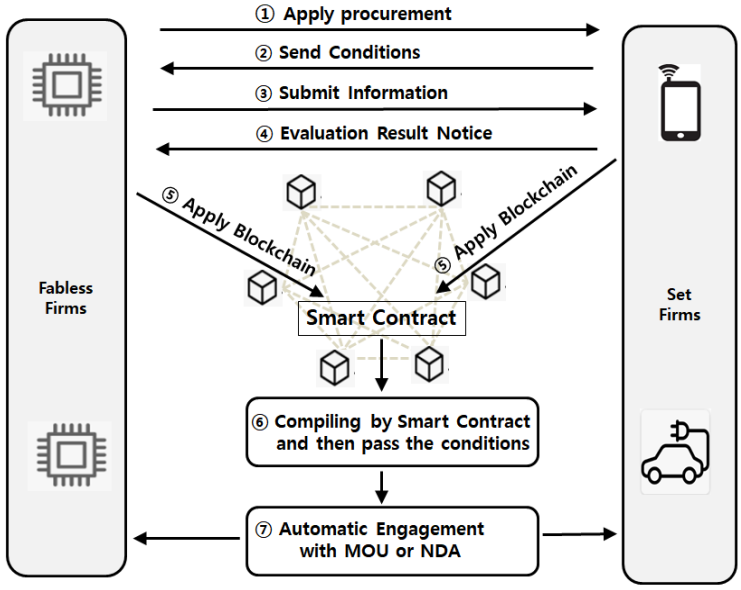

Figure 6. Smart contracts Blockchain Model Workflow

To describe the detailed model workflow in the consortium blockchain, the person in charge of the set firm checks the essential information for minimum requirement information in the fabless firm. The person in charge of the set firm confirms the minimum information provided and then, the suitability is automatically judged and automatically notified to fabless and set firms and full-scale business negotiations are held and then can start. After checking the detailed items requested by the set maker and going through the quality team's verification, it proceeds to the mass production stage if there are no problems. Figure 6 shows the F-SBM framework for applying new semiconductor parts between fabless and set manufacturers, and the sequence of scenarios is as follows:

1) Fabless firms support bidding for semiconductors to set manufacturers.
2) Set manufacturers provide the conditions for adopting the new semiconductor parts.
3) The fabless firm provides information corresponding to the conditions requested by the set manufacturer.
4) The person in charge of the set manufacture checks whether or not there is an error in the information provided by Fabless and delivers the conformity of the provided

information.

5) After checking the consistency of the results, the fabless and set manufacturers upload their respective information to the blockchain.
6) Based on the information provided by the fabless and set manufacturers, the smart contract is executed to determine whether the conditions are satisfied.
7) If the conditions of the smart contract are satisfied, set manufacturers and fabless automatically sign the NDA or MOU contract

Fabless firms can secure many business opportunities with set manufacturers through F-SBM while reducing time and effort, escaping from promoting business opportunities through the purchase team or development team of some set manufacturers through the existing limited network.

3. VERIFICATION

Model verification was conducted by frequency analysis of descriptive statistics to verify the smart contract-based blockchain transaction model. The survey sample was conducted through individual interviews or surveys of 120 people working in the semiconductor industry around the world. Descriptive statistics reviewing the distribution of survey respondents by region, the Asia-Pacific region accounted for the largest portion at 88%, followed by North America and Europe. Of the total respondents in this survey, 77% were men and 23% were women. By major, 55% of respondents majored in engineering, 19% majored in commerce, and 13% majored in natural sciences. Also, the sales and marketing department was overwhelmingly high at 58% of the departments currently working, followed by the research and development and quality teams. Since the opinions of the sales and marketing groups are judged to be important in the position of each surveyor, the share of each department in the questionnaire can be considered appropriate.

3-1 Results

Participants in this survey were of the opinion that the current semiconductor business model needs improvement. The existing transaction model makes it difficult for new fabless companies to secure business opportunities fairly, and the survey found that a more objective and transparent transaction model is needed between Set manufactures and fabless companies.

To analyze the collected data, we performed a frequency analysis of single responses using SPSS and presented the results of descriptive statistics. The analysis results were displayed using SPSS and were derived based on a sampling error range of 5%. As a result of this survey to confirm the effectiveness of presenting a blockchain-based smart contract semiconductor transaction model, 71.7% of respondents said that applying this model will help fabless companies grow and secure the business opportunities showed a response as Figure 7.

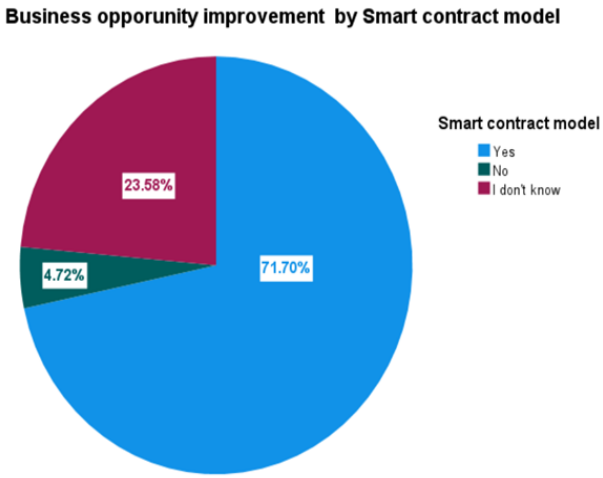

Figure 7. Model verification for Business Effectiveness

In addition, Figure 8, as a result of surveying whether fabless companies would help secure new business opportunities by securing new customers, 36% of all respondents responded that the number of fabless customers would increase by 15%. And 10% of respondents said it would increase by 30%. And 12% of people responded that the number of customers could increase by 100% compared to before. 70% of respondents said this survey would improve over the previous semiconductor business model.

Some respondents were pessimistic or unaware of the effectiveness of the new F-SBM model presented in this study. 16% of respondents said there would be no change compared to the current business model. 15% of the remaining respondents responded that they needed to learn more about the effectiveness of the research model.

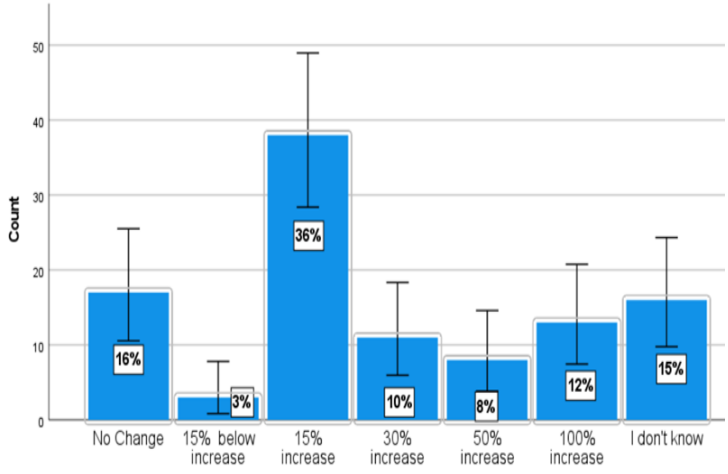

Figure 8 Model verification for Customer growth

4. CONCLUSION

Fabless companies are playing an important role in the global semiconductor industry, but except in a few countries, they still need help securing new business opportunities. Countries around the world have emphasized shared growth and cooperation with fabless companies for the growth of domestic set companies, but they continue to failure.

Accordingly, this study is the first in the fabless industry to apply a smart contract-based consortium blockchain model to the semiconductor component selection process, classify the detailed conditions of smart contracts, and evaluate the competitiveness of actual fabless companies from the following perspectives, including technology, reliability, and economic feasibility. By categorizing and defining clear evaluation items for each item, we presented a transaction model applicable to the semiconductor industry. This study demonstrated the potential for fabless companies and electronics set manufacturers to apply this business model to improve product performance at any time by building a permanent pool of competitive fabless firms.

In this study, a practical solution was presented as a new business model (F-SBM; Fabless-Smart contract-based Blockahin Model) that verified the effectiveness of the unique opportunity of the global market entry business model shown in this study and an essential issue in the growth of the worldwide system semiconductor industry was global market entry—presented a groundbreaking model for situations where the company needed to expand the development of new products and was unable to break away from the mass production structure of domestic set manufacturers. Therefore, this study presented a practical solution by verifying a new business model for new fabless semiconductor companies to enter the global market.

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