COST SAVINGS ANALYSIS OF SEMICONDUCTOR FOUNDRIES IN SOUTHEAST ASIAN COUNTRIES

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Research Project

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ABSTRACT

The semiconductor manufacturing industry is dominated by a handful of players which are mainly concentrated in developed countries such as China, Taiwan, South Korea, Japan, and the United States. These countries tend to be more expensive to run a business due to the regulations, costly tax policies, and high wages for labor. Moreover, the industry is one of the most capital intensives in the world, with costs of setting up a new foundry or fab to be in the range of 3 to 4 billion US dollars. Majority of these expenses come down to the equipment used, wages and labor costs, as well as tax regulations in each country. With that in mind, foundries or fabs can have the option to relocate or set up their production facilities in more cost-friendly countries. Specifically in Southeast Asia, such as Malaysia, Thailand, Philippines, Vietnam, and Indonesia. From this analysis, we determined that semiconductor companies, especially pure-play foundries, should heavily consider setting up fabs in Indonesia as the most cost-effective region in Southeast Asia to set up fab.

1 INTRODUCTION

Nanofabrication is a process of creation in the scale of the nano domain, usually below 100 nanometers. The term fabrication itself is taken from macro engineering, such as the design of ships, bridges, and other complex designs, pre-shaping materials of the correct properties, and assembly of subcomponents to finish a piece. The use of nanofabrication in the microelectronics industry allows for the creation of very complex integrated circuits (IC), through the creation of dense structural patterns, in a sequence of steps [1]. The creation of these structural patterns is made by modifying a functional surface, usually made out of a semiconductor such as silicone, to match and copy from the mask. Nanofabrication plays a pivotal role in the creation of integrated circuit components, such as transistors, microprocessors, and memory chips, which are constantly getting more dense and powerful due to the advances in nanofabrication technology.

Producing integrated circuits or microchips, can only be done through a dedicated facility known as a Semiconductor Fabrication Plant, or commonly called as a fab or foundry [2]. The business model of a fab can be classified into three general types, namely: Integrated device manufacturers (IDMs), fabless foundries, and pure play foundries. The difference between the three constitutes their specific roles and capabilities in producing an IC. Integrated Device Manufacturers, such as Intel, Samsung, and IBM, can design, manufacture, and sell microchips through their very own in-house processes. Fabless foundries on the other hand, do not manufacture their own chips, instead only design, and outsource the manufacturing or fabrication process to pure-play foundries. Examples of fabless foundries are Nvidia, Qualcomm, and AMD. Lastly are pure-play foundries, such as Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC), which usually produce integrated circuits exclusively for other companies [3].

With such complex processes and highly specialized equipment, the semiconductor industry is one of the most competitive in the world, with only around 494 fabs under 144 companies located in 22 countries [4]. Despite having facilities in 22 countries, semiconductor companies, primarily the pure-play foundries, are concentrated in 2 major areas, East Asia, and the United States. To be more precise, at the end of 2020, the top countries for 300mm wafer capacity based on fab locations are concentrated in South Korea, Taiwan, Japan, China, and the United States [5].

At first glance, the concentration of fabs facilities in these countries seems to be in locations where are generally categorized as developed and where overhead costs such as labor and electricity are more costly in comparison to developing countries, such as Indonesia or any other ASEAN countries. This paper aims to figure out and identify the business prospects of building a pure play semiconductor fab in other countries, specifically the ones located in Southeast Asia whether it would still be more profitable knowing that resources and costs can be lowered, thus resulting in higher profits when compared to facilities in countries like the United States, Taiwan, and the likes.

2 BACKGROUNDS

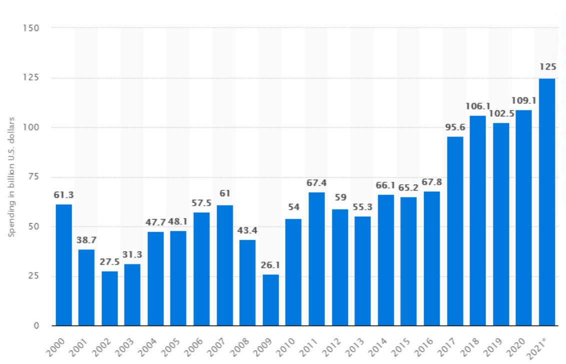

Figure 1: Capital expenditure in the global semiconductor industry from 2000 to 2021 (in billion USD) [6]

The integrated circuit manufacturing and nanofabrication industry is one of the most capital intensives in the world, with high barriers of entry due to the very high costs needed in producing microchips. In 2020, the capital expenditure for the global semiconductor industry amounted to $109.1 billion and is predicted to increase by 15 percent to $125 billion by the end of 2021 [6]. The capital needed to set up a standard 300 mm wafer fab ranges around 3 to 4 billion dollars, with the latest and leading-edge facilities made by TSMC and proposed by Intel reaching figures up to 20 billion dollars [7,8].

Moreover, the nature of the industry itself requires fabs to rely on producing as many semiconductors as possible in order to maximize the economies of scale in order to stay profitable. This ultimately means maximizing manufacturing output given the same process and steps, hence opting for manufacturing semiconductors on a 300 mm wafer compared to 200 mm ones would provide a greater return for the manufacturer because it yields more semiconductor chips for similar time and processes. Although equipment for 300 mm wafers are 20-40 percent more expensive compared to the 200 mm wafers, the cost per chip would also decrease by 27-39 percent [9]. Since equipment is also very specialized, upgrading a previous generation equipment to facilitate the next generation manufacturing processes is also considered as impractical and unviable. This leads to equipment of 200 mm wafers to focus more on semiconductor devices meant to facilitate last decade’s electrical products, and producing semiconductors for the current and upcoming trends, such as powerful logic processors, memory, graphics card, used in smartphones, personal computers, and self-driving cars would be pretty much impossible. With this information, it would be more reasonable to opt for a business model catering to the production of 300 mm wafers in order to facilitate potential future demands and technologies.

The Southeast Asia region consists of eleven neighboring countries which are diverse in their social, cultural, and political aspects of their own. The eleven countries are Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, and Vietnam. Furthermore, these countries are one of the most dynamic regions in the world from an economic standpoint, making it a growing international significance [10].

However, this paper will focus on the 5 emerging and developing countries in the Southeast Asia region, which automatically exclude Singapore as it is considered as a developed country with one of the highest average wages in Asia, and Laos, Timor-Leste, Cambodia, Brunei, Myanmar as these countries is deemed too unstable economically and politically, which poses a major threat for businesses looking to expand.

In the order of gross domestic product (GDP), the five countries are Indonesia, Thailand, the Philippines, Vietnam, and Malaysia [11]. Moreover, these emerging countries are more economically competitive whilst maintaining decent political stability, making it more attractive for companies to invest or set up their fabrication plants. It is also worth noting that currently, the only Southeast Asian countries that have a fab facility that fabricates semiconductors are Malaysia, Singapore, and Thailand [12, 13, 14].

3 FAB COST STRUCTURE

In determining the cost structure of a fab, several key factors come into play. Generalized, the factors constitute: Labor cost (10-15%), Material cost (35-40%), Capital cost (40-50%) [15]. More detailed factors regarding capital costs of fabs can also include the following items: (1) Fab concept design, (2) Fab capacity, (3) Factory layout, (4) Products to be fabricated, (5) Fab location, (6) Equipment selection, and (7) Equipment acquisition method [16]. Referring to these factors, the components that can be controlled, or would change, in achieving a more cost-efficient fab if one were to be built in another country are labor costs and capital costs. The capital cost can also be broken down into two more specific parts, which are fab location, which will affect the wage of workers and income tax that applies to companies, and equipment acquisition method. All of these factors combined can contribute to the cost efficiency process that might differ greatly for fab facilities looking to expand or set up a facility in another geographical region or country.

3.1 LABOR COST

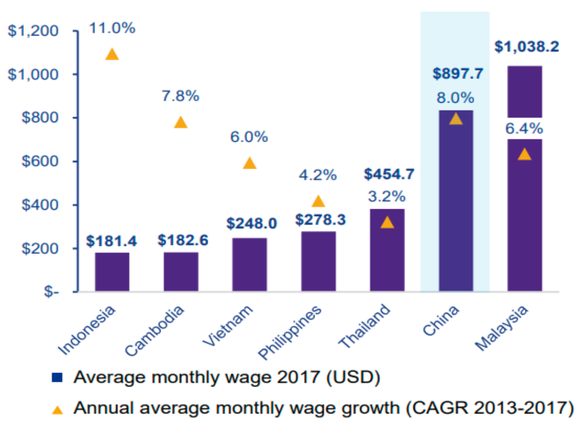

Figure 2: Average monthly wage of Southeast Asian countries [18]

In terms of a cost from an average labor wage, the Southeast Asia region provides one of the most competitive and lowest wages for manufacturing companies around the world, such as how China had always been a benchmark and highly known for its cheap labor prices, which does not seem to be the case anymore. To compare, the average monthly wage in Taiwan is around $ 1,304, which is 31.15% higher than the average monthly wage in China of around $897.7 [17,18]. According to 2017 research done by KPMG, the average labor wage between the five countries showed that Malaysia has the highest average monthly wage of $1,038.2 - which in turn also exceeds China's average monthly wage of $897.7. Thailand comes next, being around 2.5 times cheaper than Malaysia and half of that of China's, amounting to an average of $454.7. Philippines and Vietnam follow through with near identical averages of $278.3 and $248 respectively. However, when it comes to the lowest labor cost on average, Indonesia totals to a monthly wage of only 181.4 U.S. dollars per month, cheapest amongst all neighboring countries, even Cambodia [19].

Indonesia's labor costs are one of the lowest in Asia, such as that electronics manufacturing cost for labor in Indonesia is 60 percent the cost of that in China, which also prompted Foxconn, one of the world's largest electronics component manufacturers, to invest in a $1 billion production plant in the country [20].

Region	Labor Cost Savings
Malaysia	20.38%
Thailand	65.13%
Philippines	78.65%
Vietnam	80.98%
Indonesia	86.08%

Table 1: Estimated labor cost savings in Southeast Asian countries compared to Taiwan, ROC

Referring to the Taiwan Semiconductor Manufacturing Company (TSMC) 2019 annual report, the total cost of labor for all 44,058 employees amount to NT$ 96,559,369,000 or US$ 3.186 billion (NT$ 1 = US$ 0.033, as of 31 December 2019); with the average annual labor cost for each employee to be around NT$ 2,183,000 or US$ 72,039 [21]. Taking Taiwan's TSMC as the subject of comparison, the average labor cost if manufacturing were to be done in these five Southeast Asian countries would result in a hypothetical cost savings ranging from 20.38 percent (US$ 649 million) in Malaysia, up to 86.08 percent (US$ 2.743 billion) in Indonesia.

Region	Total Net Labor Cost Savings
Malaysia	2.03% to 3.05%
Thailand	6.51% to 9.76%
Philippines	7.86% to 11.79%
Vietnam	8.09% to 12.14%
Indonesia	8.60% to 12.91%

Table 2: Estimated total net labor cost savings for foundries in Southeast Asian countries

Furthermore, given that labor costs make up 10-15 percent of a fab's cost structure as previously mentioned, foundries would be able to save total company expenses by 2.03 percent to 3.05 percent in Malaysia, up to a hypothetical 8.60 percent to 12.91

percent in Indonesia. Overall, Indonesia's labor wages are the most competitive for manufacturing, which can be beneficial for future fabs.

3.2 REGIONAL CORPORATE INCOME TAX RATE

Company	**Effective Tax Rate**	**Country**
Samsung Electronics	27.3%	South Korea
SK Hynix	23.7%	South Korea
Intel	16.7%	United States
TSMC	11.4%	Taiwan, ROC

Table 3: Effective income tax rates imposed on different semiconductor companies in 2020 [21]

One of the greatest advantages when it comes to manufacturing in a different location or country is that different tax laws and rates apply. In 2020, South Korean based semiconductor companies like Samsung and SK Hynix were imposed corporate income tax (CIT) north of 20 percent, specifically 27.3 percent and 23.7 percent respectively. Other companies like Intel based in the U.S. and Taiwan's TSMC are also subject to corporate income tax of 16.7 percent and 11.4 percent [21]. There are, however, other countries that offer lower tax rates and incentives for certain industries.

Country	**General CIT**	**Tax Incentive**
Malaysia	25%	0% up to 17.5% CIT for 5 years
Thailand	20%	0% CIT for 10 years
Philippines	25%	0% for 4 to 7 years, followed by 5% CIT for 10 years
Vietnam	20%	0% for 4 years, followed by 5% for 9 years, then 10% CIT for 15 years
Indonesia	20%	0% for 20 years followed by 10% CIT for 2 years

Table 4: Corporate income tax according to tax incentives for Southeast Asian countries [22, 23, 24, 25, 26]

Malaysia has a tax incentive program named Pioneer Status (PS) which grants tax exemption from statutory income by 70 percent up to 100 percent (for high-tech industries) for 5 years, which translates to zero up to 17.5 percent of corporate income tax for 5 years. Without incentives, the standard CIT would cost companies 25% from their income [22]. Next is Thailand, which also offers complete 0 percent tax holidays and incentives for technology-intensive manufacturing which requires front-end capital, such as wafer fabrication for 10 years, as opposed to the general CIT of 20 percent [23]. The Philippines also offers an Income Tax Holiday (ITH) for 4 to 7 years, as determined by the Strategic Investment Priority Plan (SIPP), followed by a 10-year Special Corporate Income Tax (SCIT) of 5 percent, as opposed to the standard 25 percent CIT [24]. For Vietnam, the tax incentive for the country's semiconductor industry allows for zero percent corporate income tax for the first 4 years The government also allows an additional 5 percent CIT incentive of 15 years for international scale industries, such as semiconductor fabrication, for the next 15 years, as opposed to the standard 20 percent CIT rate [25]. Lastly is Indonesia, which offers a tax incentive program in the form of tax holiday facilities for companies in high-priority pioneering sectors, semiconductors included, for 20 years and followed by a 2-year incentive of 10 percent corporate income tax, contrary to the general 20 percent CIT rate. Another criterion, however, is that a minimum of 500-billion-rupiah investment, or approximately US$ 35 million (US$ 1 = Rp 14.300, as of 2 June 2021) should be fulfilled in order to become eligible, as it is similar to the other countries [26].

Country	**Tax Paid***	**Total**
Malaysia	$0 (5 years); $6.25 M (25 years)	$6.25 million
Thailand	$0 (10 years); $4 M (20 years)	$4 million
Philippines	$0 (7 years); $0.5 M (10 years); $3.25 M (13 years)	$3.75 million
Vietnam	$0 (4 years); $0.45 M (9 years); $1.5 M (15 years); $0.4 M (2 years)	$2.35 million

Indonesia	$0 (20 years); $0.2 M (2 years); $1.6 M (8 years)	$1.8 million

* Assuming net annual income of $1 million for 30 years

Table 5: Comparison of taxes paid according to tax incentives for Southeast Asian countries

Applying the tax incentives of each country with the assumption that a fab has an annual taxable income of $1 million, for a duration of 30 years, the amount of taxes paid in each country greatly differs. A fab in Malaysia, for instance, might have to pay $6.25 million in taxes over the 30-year period, as opposed to only $2.35 million in Vietnam. However, if fabs were to be built in Indonesia, the manufacturer would only have to pay $1.8 million, the lowest among these 5 Southeast Asian countries. It also needs to be mentioned that this scheme does not yet include additional tax incentives that may come from other manufacturing activities, such as water usage, electricity, research, and development, and so forth. However, for an initial assessment from a tax regulation perspective, Indonesia seems the most promising in terms of cost-savings for a semiconductor fab facility, which may potentially reduce tax burden and increase net profit for the company by around 10 to 20 percent.

3.3 EQUIPMENT ACQUISITION METHOD

There are two major ways of how a fab acquires their equipment, buying and leasing. Buying an equipment, new or used, means having full ownership of the equipment at hand. Leasing, however, means borrowing equipment for an agreed period of time in exchange for a sum of money, usually through an asset management company. Leasing can be beneficial for fabs that do not want to have a large capital expenditure at the very beginning and/or look forward to upgrading their equipment a few years down the line since fabrication equipment are not upgradable in the first place. Another reason to look into leasing instead of purchasing equipment is that this machinery will depreciate overtime, losing its value and becoming a cost-driver on its own. Leasing fab equipment can save manufacturers 30 percent in capital expenditure and costs compared to purchasing and storing one for the long run; so instead of paying $5 million for a stepper, the fab only needs to cost $3.5 million for the equipment and not have to worry of the risks of depreciation, maintenance, storing, disposing and have the ability to swap it with a more advanced model [27]. With equipment making up roughly 35 to 40 percent of a fab's capital expenditures, manufacturers can look to save up to another 4 to 6 percent from the overall total cost of setting up fab.

4 POTENTIAL SALES

GlobalFoundries' US$ 4 billion Singapore fab produces semiconductors on 300mm wafers and has a production capacity of 450,000 wafers per year [28]. This translates to an average production output of 37,500 wafers per month or 8,654 wafers per week.

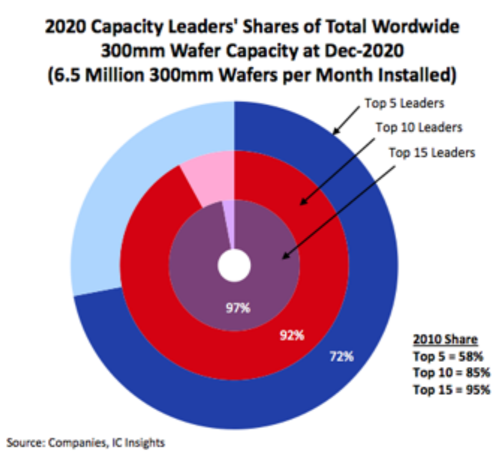

Figure 3: Shares of Total Worldwide 300mm Wafer Capacity (December 2020) [29]

The total 300mm worldwide wafer capacity during December 2020 amounts to 6.5 million wafers every month [29]. With our new hypothetical Indonesian fab's production capacity being 37,500 per month, this totals to a market share of around 0.58% of the global wafer capacity. The fab itself will also be fabricating chips on 12-inch (300 mm) wafers with each wafer's total area being 72,965mm^2. Assuming the new fab were to fabricate Qualcomm's Snapdragon 5G X55 modem chip for the latest iPhone 12 lineup, a 12-inch wafer would fit 2211 X55 dies, with each chip die being 33mm^2 in area size [30]. Following the hypothetical wafer capacity output of 37,500 wafers per month, the new Indonesian fab would produce around 82.9 million chip die per month. The price of one chip is estimated to be around US$125 [31], which totals monthly sales for the fab to be around US$ 10.3 billion, assuming that the fab is running at maximum capacity and all chips are sold instantly.

Gross Profit Margin = (Net Sales - COGS) ÷ Net Sales

$$Net\ Profit\ Margin = Net\ Income \div Net\ Sales$$

The average gross profit margin and net profit margin for the semiconductor industry are

32.91% and 15.44% respectively [32]. Using the percentage of the gross profit margin and substituting 'net sales' with $125 per chip, the cost of producing one chip before markup is $83.86, and the net income received by the fab for every chip sold is $19.3. This results in the fab profiting for $1.6 billion each month; again, assuming production is in full capacity, with 100 percent yield, and chips being instantly sold, where in actuality, fabrication processes like these can take hundreds of steps and take 6 to 8 weeks to complete.

However, this does not include yet the cost efficiency factors that can be included through the labor, tax, and equipment savings. If the initial cost of producing one chip amounts to $83.36, an additional 20 percent to 40 percent savings can save the company $16.67 to $33.34 per chip, or with the ideal output rate; $1.38 billion to $2.7 billion per month.

5 CONCLUSIONS

When comparing the five Southeast Asian countries, Indonesia seems to provide the most cost-effective location for fab manufacturing out of the rest, from a labor cost aspect, as well as from tax regulations and incentives perspective.

Cost Variables	**Estimated Savings**
Labor costs	6 to 9 percent
Tax holiday facility	10 to 20 percent
Equipment leasing	4 to 6 percent
Total	**20 to 35 percent**

Table 6: Estimated summary of total cost savings from a fab in Indonesia

Building or relocating fabs to Indonesia indicates more reduction to the cost and expenses when compared to building one in Malaysia, Thailand, Philippines, Vietnam, even in Taiwan, and China. On average, having fabs in Indonesia would benefit manufacturers in labor costs by 6 to 9 percent, tax exemption through tax holiday facilities by 10 to 20 percent, and through equipment leasing by 4 to 6 percent. This essentially allows fabs to save up from 20 to 35 percent in costs and increase their margin of profits. If we were to benchmark GlobalFoundries' recent fab made in Singapore earlier this year which cost an initial investment of US$ 4 billion, assuming all other parameters are constant, GlobalFoundries could have saved US$ 800 million to US$ 1.4 billion by building a fab in Indonesia. This does not also take into account the annual overhead cost of running a fab with cheaper labor wages, tax, and also all other process activities that may differ between countries.

Although Indonesia is not primarily known for being a major player in the electronics and in the technology manufacturing supply chain, it is by far the largest country by economy in the region, has the largest population consisting of nearly 270 million people, and is also in the midst of a demographic bonus where the number of productive aged individuals will experience a surplus of quantity over the non-productive citizens. In turn, the quality of workforce, skills, and economy is projected to drastically increase [33]. This further leaves a bigger room for companies to expand and build manufacturing facilities in the country knowing that there will be rapid expansion in the economy and thus also a larger market and fast-growing infrastructure development.

Despite some possible uncertainty that may drive off companies from investing in Indonesia, the ongoing de-regulation, economical packages, and fast-growing economy and development, may be very attractive for companies to set-up a semiconductor foundry or fab in the country [34]. Upon the initial research and the huge potential to save costs, I would conclude that setting up semiconductor microfabrication facilities or fabs in Indonesia to be a decision that should be heavily considered.

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