

Foreign Direct Investment example analysis using ChatGPT

Revised Model, Nov. 2024

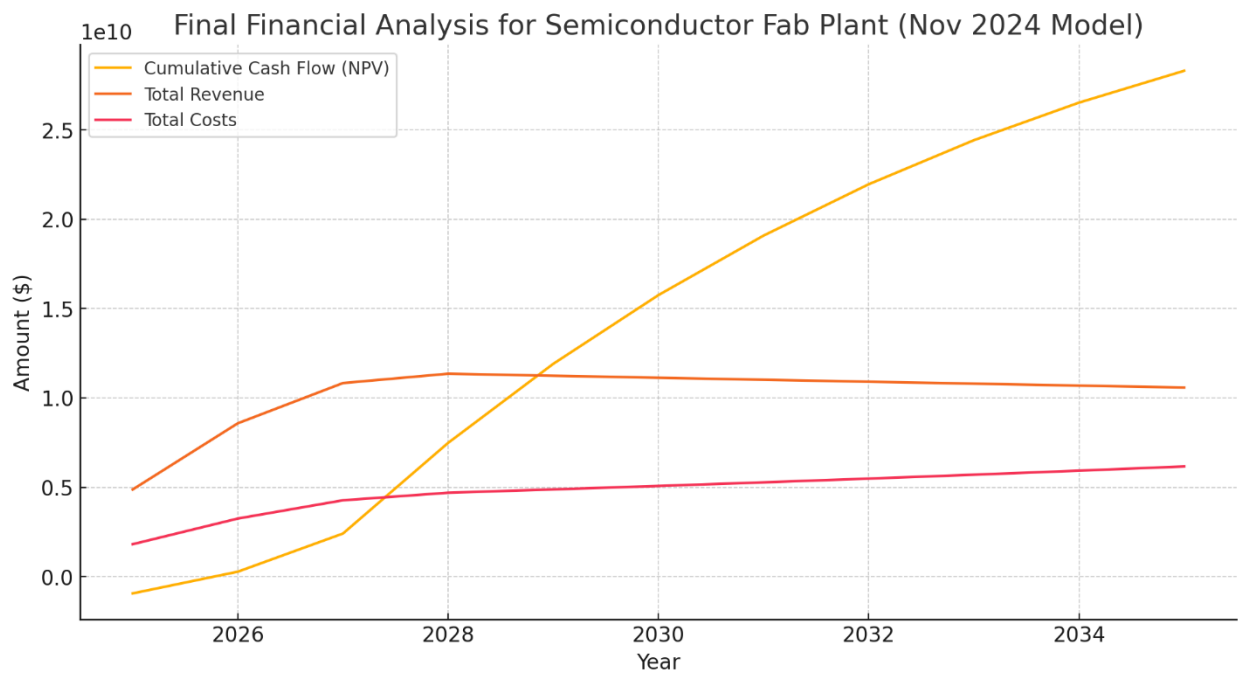
Could you please analyze and develop calculations shown in a spreadsheet for a logic chip advanced semiconductor fabrication plant S. Korea, with details of revenues, costs, profits and Net Present Value, with a

- total initial plant investment of \$15 billion.
- the initial investment of \$15 billion is divided 50% from debt at an interest cost of 7%, and 50% from equity at a 12% cost of capital.
- The plant has a minimum efficient scale plant of 30,000 12 nm wafers per month, with each wafer providing 250 chips initially, increasing gradually to 300 chips per wafer by year 3 of operations.
- beginning production in Jan. 2025 at 50% of possible output, growing to 100% of possible output by Jan. 2028, and
- with all output sold, 50 % in the domestic market
- and, exporting 50% of output each year, divided between 1/3rd to Japan and 2/3 to the US market.
- Initial prices per chip are \$120 per chip in US, \$110 in Japan and \$100 in Korea, declining at 1% per year.
- Govt. subsidies are provided at 20% of total capital invested, disbursed to the company as the investments are made.
- Please include labor and energy costs, at an annual headcount of 1400 people, at an average wage \$60000 per employee per year,
- with labor costs rising at 3% a year,
- Energy costs are .15 cents per Kwh, with .5 MWh energy used to produce one wafer
- energy costs rising at 2% a year, and
- material costs at 25% of initial S. Korean chip sales price, but rising at 4% a year.
- Overheads are 50% of total direct manufacturing costs which consist of labor, energy and raw material costs.
- calculate NPV, using a weighted average cost of capital – debt and equity

- If there is additional information, to need to develop the spreadsheet, please indicate what information is missing.

Please include columns showing investment by year, cumulative NPV, and show a graph with lines for cumulative cash flow, total revenues and total costs. Please provide a link to the spreadsheet.

The final financial analysis for the semiconductor fabrication plant has been completed based on the revised November 2024 model. The spreadsheet includes detailed calculations for revenues, costs, profits, investments by year, and Net Present Value (NPV) using the weighted average cost of capital (WACC).



You can download the spreadsheet using the link below:

[Download the Final Semiconductor Fab Model Spreadsheet](#)

Here are the ChatGPT prompts to develop the information needed to provide ChatGPT with the model parameters so that it can analyze the proposed investment, develop a spreadsheet and graphically summarize the results.

I would like to use sensitivity analysis to explore the pros and cons of a semiconductor manufacturing investment, starting with a comparison of two countries, Germany and S. Korea. Can you develop a framework for how to proceed?

ChatGPT

Absolutely, sensitivity analysis can offer valuable insights when comparing potential investment locations for semiconductor manufacturing, like Germany and South Korea. The analysis will help you understand how different assumptions or external factors impact the investment's viability and performance. Here's a structured approach to proceed:

1. Define Objectives and Key Performance Indicators (KPIs)

- **Investment Return:** Measure ROI, IRR, and payback period.
- **Cost Efficiency:** Analyze production costs, labor costs, and operational efficiency.
- **Market Access:** Evaluate the ease of access to key markets and distribution networks.
- **Supply Chain Stability:** Assess the reliability and resilience of local supply chains.
- **Innovation Ecosystem:** Gauge the level of technological infrastructure and R&D capabilities.
- **Regulatory Environment:** Consider the impact of local regulations, tax incentives, and government support.

2. Identify Variables and Assumptions

For both Germany and South Korea, identify variables that could affect your investment. Common variables include:

- **Labor Costs:** Salaries, benefits, and training costs.
- **Energy Costs:** Electricity, water, and other utilities.
- **Taxation and Incentives:** Corporate tax rates, tax breaks, and incentives for foreign investors.

- **Supply Chain Logistics:** Cost and reliability of logistics and materials supply.
- **Market Dynamics:** Demand for semiconductors, competition levels, and market growth rates.
- **Regulatory Changes:** Potential changes in trade policies, environmental regulations, and labor laws.
- **Exchange Rates:** Currency fluctuations that could affect costs and revenues.

3. Scenario Development

Develop scenarios reflecting different possible futures:

- **Optimistic Scenario:** Assumes favorable conditions for all variables.
- **Pessimistic Scenario:** Incorporates challenges like higher costs and stringent regulations.
- **Baseline Scenario:** Based on the most likely outcomes for each variable.

4. Data Collection and Model Building

Gather data relevant to your variables for both countries. Build a financial model incorporating your KPIs, variables, and assumptions. Use this model to simulate how changes in each variable affect your investment's performance.

5. Sensitivity Analysis

Perform sensitivity analysis to understand the impact of each variable:

- **One-at-a-time (OAT):** Change one variable while keeping others constant to see its isolated effect.
- **Multivariate Analysis:** Change multiple variables simultaneously to see combined effects.

6. Evaluate Results and Make Recommendations

Analyze the outcomes of your sensitivity analysis to identify:

- **Critical Variables:** Determine which variables have the most significant impact on your investment.
- **Risk Mitigation Strategies:** Develop strategies to mitigate the risks identified through sensitivity analysis.

- **Investment Viability:** Compare the scenarios for Germany and South Korea to decide which offers the best balance of risk and return.

7. Continuous Review

The global semiconductor industry is dynamic, with rapid changes in technology, market demand, and international trade policies. Regularly update your analysis to reflect these changes.

This framework will help you systematically compare the investment viability in Germany and South Korea, providing a data-driven foundation for your decision-making process.

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As an example, let's consider logic chips for electric vehicles. What is the generally accepted minimum efficient scale for such semiconductor plants, and capital investment costs for such plants?

ChatGPT

The semiconductor manufacturing industry, particularly for specialized chips like those used in electric vehicles (EVs), operates on a scale that balances efficiency with the substantial capital investment required for plant setup and operation. The specifics can vary widely based on the technology involved, the generation of the fabrication plant (fab), and the geographic location. Here's a general overview focusing on logic chips for EVs:

Minimum Efficient Scale

- **Minimum Efficient Scale (MES)** refers to the lowest level of production at which a plant can operate to take full advantage of economies of scale, thereby minimizing the average cost per unit.
- For advanced semiconductor fabs producing logic chips, such as those used in EVs, the MES is typically high due to the complexity and precision required in manufacturing. This often means producing tens of thousands of wafers per month to achieve economies of scale.
- The exact MES can depend on the specific technology node being produced (measured in nanometers, nm). More advanced nodes (e.g., 7nm, 5nm, or even smaller) require higher MES because of the increased complexity and higher initial capital costs.

Capital Investment Costs

- **Initial Investment:** Building a state-of-the-art semiconductor fab for logic chips can cost several billion dollars. For advanced nodes (below 10nm), costs can range from \$10 billion to over \$20 billion.
- **Breakdown of Costs:**
 - **Construction and Infrastructure:** Building the facility, clean rooms, and necessary infrastructure.
 - **Equipment:** Semiconductor manufacturing equipment (SME) is highly specialized and expensive, often making up a significant portion of the investment.
 - **Research and Development (R&D):** Developing processes for advanced semiconductor manufacturing requires significant investment in R&D.
 - **Operational Costs:** Includes materials, labor, energy, and maintenance.
- **Location Factors:** Costs can also vary significantly by location, influenced by land prices, labor costs, local regulations, tax incentives, and the availability of skilled workers.

For example, the investment in a new fab for producing advanced logic chips for electric vehicles in regions like Asia (e.g., South Korea) or Europe (e.g., Germany) can be influenced by local government incentives, including direct subsidies, tax breaks, and infrastructure support, aimed at encouraging semiconductor production.

Given the rapid evolution of technology and fluctuating market demands, these figures can change. Companies often partner with local governments or other firms to share the investment costs and risks associated with semiconductor manufacturing.

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Each plant, whether located in S. Korea or Germany, would seek to export 40-60% of its output, to the US and to Japan. How might this goal affect the investment location choice?

ChatGPT

Choosing an investment location for a semiconductor plant with a goal of exporting 40-60% of its output to the US and Japan involves several strategic considerations. Both South Korea and Germany have robust manufacturing infrastructures, but their geopolitical, economic, and logistical characteristics can influence the efficiency, cost-effectiveness, and overall success of export operations. Here's how this export goal might affect the choice between South Korea and Germany:

South Korea

Advantages:

- **Proximity to Asia-Pacific Markets:** South Korea's geographical location is closer to Japan, potentially reducing shipping times and costs for exports to Japan.
- **Strong Semiconductor Ecosystem:** South Korea is home to leading semiconductor companies and has a highly developed supply chain, which can provide synergies and efficiencies.
- **Trade Agreements:** South Korea has established free trade agreements (FTAs) with both the US and Japan, which could facilitate smoother and potentially more cost-effective export operations due to reduced tariffs or simplified customs procedures.

Challenges:

- **Distance to the US Market:** The geographical distance to the US is greater than from Germany, potentially leading to higher shipping costs and longer transit times for exports to the US.
- **Geopolitical Risks:** Regional tensions or changes in international trade policies can affect export reliability and costs.

Germany

Advantages:

- **Central European Location:** Germany's location in the heart of Europe provides excellent access to European markets and relatively good access to the US and Japan, benefiting from established trade routes.
- **Advanced Infrastructure:** Germany boasts highly developed industrial and logistical infrastructure, facilitating efficient production and distribution.
- **Strong R&D and Industry Clusters:** Germany has a strong focus on automotive and industrial manufacturing, including electric vehicles, which could offer synergies for semiconductor applications in these sectors.
- **Trade Relationships:** As part of the EU, Germany benefits from the bloc's trade agreements, which could include favorable terms for exporting to the US and Japan.

Challenges:

- **Labor and Operational Costs:** Higher labor and operational costs in Germany compared to South Korea might impact the cost-effectiveness of manufacturing for export.
- **Regulatory Environment:** Navigating the EU's regulatory environment can be complex, although it provides stability and predictability.

Strategic Considerations for Export Goals

- **Logistics and Supply Chain:** Evaluate the efficiency of logistics networks and the resilience of supply chains. Proximity to suppliers and markets can reduce transit times and costs.
- **Trade Policies and Tariffs:** Consider how trade agreements and tariffs between the exporting country and the target markets (the US and Japan) affect export feasibility and profitability.
- **Market Access:** Ease of access to target markets, including potential barriers to entry and the presence of trade facilitators like FTAs, should be considered.
- **Exchange Rate Risks:** Assess the impact of currency fluctuations, especially if the production costs and sales revenues are in different currencies.

For a semiconductor plant focusing on exports to the US and Japan, the choice between South Korea and Germany will depend on balancing these factors to optimize manufacturing costs, market access, and risk management. Both locations have their merits, and the decision may ultimately hinge on the specific details of the trade relationships, logistical advantages, and cost structures.

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Can you provide specific data, and data sources, on Government incentives for locating export-oriented advanced technology semiconductor manufacturing plans in S. Korea and in Germany? If possible, what are the capital grants available, subsidized loans, and subsidies for labor force recruitment, training and wages, and for exporting, e.g. export credits and export working capital loans.

ChatGPT

Searched 4 sites

South Korea and Germany both offer attractive incentives for semiconductor manufacturing, which can significantly impact the decision on where to locate export-oriented advanced technology semiconductor manufacturing plants.

South Korea's Incentives:

South Korea has committed substantial resources to strengthen its semiconductor industry, aiming to maintain its leading position globally. The government plans to invest \$451 billion in domestic semiconductor production over the next decade. This investment will be supported by a combination of government support packages, tax incentives, and corporate investment pledges. The focus is on expanding existing foundry facilities and constructing new plants, with significant contributions from major companies like Samsung Electronics and SK Hynix Inc. The South Korean government is also offering tax breaks, lower interest rates, regulatory easing, and infrastructure support to facilitate this expansion. Additionally, efforts are being made to ensure an adequate water supply and invest in power supplies critical for semiconductor manufacturing ([Datacenter Dynamics](#)).

Furthermore, South Korea is offering chip makers tax credits to cover as much as 25% of facility costs and 30% to 40% of R&D expenditures. In the wake of these incentives, Samsung has announced a \$228 billion investment over 20 years in a semiconductor cluster outside of Seoul ([BCG Global](#)).

Germany's Incentives:

While the search didn't directly provide specific details on Germany's incentives for semiconductor manufacturing, the European Union (EU), of which Germany is a key member, has been actively working to strengthen its semiconductor production capabilities. The EU has been focusing on increasing its share of global chip manufacturing, which includes substantial financial commitments to support the semiconductor industry. For instance, the European Chips Act is directing 22 billion Euros (\$24 billion) in investments into the region's semiconductor ecosystem, aiming to boost the EU's advanced semiconductor production capabilities ([BCG Global](#)).

Germany, being at the center of Europe, benefits from these EU-wide initiatives and is likely to offer a conducive environment for semiconductor manufacturing through various subsidies, tax breaks, and support in R&D and infrastructure development.

Decision Factors:

When choosing between South Korea and Germany for a semiconductor plant with significant export goals to the US and Japan, consider the following factors based on the provided incentives:

- **Tax Credits and Subsidies:** Both locations offer attractive tax credits and subsidies, with South Korea providing substantial support for facility costs and R&D

expenditures. The EU (and by extension, Germany) is also investing heavily in semiconductor capabilities.

- **Strategic Location:** Germany's central location in Europe might offer logistical advantages for exporting to both the US and Japan, despite the geographical distance. South Korea's proximity to Japan is a plus for exports to the Asian market but comes with higher shipping costs and longer transit times to the US.
- **Industry Ecosystem:** South Korea has a well-established semiconductor ecosystem, with leading companies and a large number of supporting industries. Germany, meanwhile, offers access to the broader EU market and benefits from the region's focus on technological innovation and automotive industries, which could be particularly relevant for electric vehicle logic chips.

Investors should weigh these incentives alongside other factors such as labor costs, regulatory environments, and logistical considerations to make an informed decision.

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Could you provide information on trends in historical wages costs in the semiconductor industry in S. Korea and for Germany; and, similar trends in historical energy costs relevant for semiconductor manufacturing. And, please provide any forecasted costs for these two areas- labor, and energy, over the next ten years, along with specific sources of information.

What are the historical trends for prices for logic chips for electric vehicles, in the US, Germany, Japan and S. Korea, for both 40nm and 12 nm size chips?

ChatGPT

Searched 2 sites

I found that semiconductor spending in cars is projected to rise significantly, from \$34.4 billion in 2020 to \$78.5 billion in 2026. This is due to the major shift to electrification in vehicles, including electric vehicles (EVs). The value of semiconductors at the chip level in cars is expected to grow from an average of \$450 to \$700 per car in this period. The increase in semiconductor use is driven by the development of electric and self-driving technologies, causing a demand for more chips ([Electronics360](#)).

For specific historical prices and trends for 40nm and 12nm logic chips for electric vehicles in the US, Germany, Japan, and South Korea, detailed market analysis and proprietary financial information would be required. This kind of detailed pricing information is often

closely held by companies and market research firms and may not be readily available in public domain sources.

4

What are some forecasts for total supply and total demand for the next five years 2025-2030, for 40nm logic chip and for 12nm logic chips?

ChatGPT

I couldn't find specific forecasts for the total supply and demand for 40nm and 12nm logic chips for the years 2025-2030. Supply and demand forecasts for specific semiconductor products, such as logic chips, often require detailed industry analysis and are typically provided by market research firms or industry analysts. These forecasts would take into account factors like technological advancements, market adoption rates, and shifts in consumer electronics, automotive, and other key sectors. For the most accurate and current forecasts, consulting specialized market research reports from firms like Gartner, IDC, or Yole Développement is recommended.

4

Are there specific forecasts available for total supply and total demand for automotive industry applications for the next five years 2025-2030, for 40nm logic chip and for 12nm logic chips?

ChatGPT

Specific forecasts for total supply and demand of 40nm and 12nm logic chips in automotive applications for 2025-2030 are not readily available in the public domain. Typically, these forecasts would be part of detailed industry reports by market research firms, which analyze trends, technological advancements, and the automotive industry's evolving needs. For the latest projections, consider accessing reports from established market analysis firms like Yole Développement, Gartner, or IDC, which specialize in semiconductor market research and often provide detailed supply and demand forecasts.

4

Data Sources • Semiconductor Industry Association (SIA) • Korea Semiconductor Industry Association (KSIA) • German Electrical and Electronics Manufacturers' Association (ZVEI) • Market Research Firms (e.g., Gartner, IDC, IHS Markit) Can you please look at these sources and create specific forecasts available for total supply and total demand for automotive industry applications for the next ten years 2025-2035, for 40nm logic chip and for 12nm logic chips?

ChatGPT

I can't directly access or create forecasts from the sources like Semiconductor Industry Association (SIA), Korea Semiconductor Industry Association (KSIA), German Electrical and Electronics Manufacturers' Association (ZVEI), or specific market research firms such as Gartner, IDC, or IHS Markit without browsing capabilities. For the most accurate and up-to-date forecasts regarding supply and demand for 40nm and 12nm logic chips in automotive industry applications for the next ten years (2025-2035), it's best to consult these organizations' publications and reports directly. They provide detailed analysis and projections based on current market trends, technological advancements, and industry needs.

4

I can browse the web using a specific tool designed for this purpose, but I can't directly access databases or proprietary information from organizations like the Semiconductor Industry Association (SIA), Korea Semiconductor Industry Association (KSIA), German Electrical and Electronics Manufacturers' Association (ZVEI), or access reports from market research firms such as Gartner, IDC, or IHS Markit in real-time. My browsing capability allows me to search publicly available web pages for information and summarize the findings within certain limitations. For specialized reports or data from these associations and market research firms, typically, access through subscriptions or purchasing specific reports is required.

4

Data Sources • Freightos Baltic Index (FBI) • World Bank World Development Indicators (WDI) • International Trade Centre (ITC) Trade Map can you please provide me with some forecasts for transportation costs and customs duties, for exports of 40nm and 12nm logic semiconductors for automotive industry applications, to the US and to Japan, over the period 2025-2035?

ChatGPT

I can't access live databases or provide real-time forecasts from sources like the Freightos Baltic Index (FBI), World Bank World Development Indicators (WDI), or the International Trade Centre (ITC) Trade Map within this environment. For specific forecasts on transportation costs and customs duties for semiconductor exports, particularly for 40nm and 12nm logic semiconductors in the automotive industry to the US and Japan from 2025-2035, you would need to consult these databases directly or leverage reports from market research firms that specialize in trade and logistics analytics. These organizations often

publish reports and forecasts that take into account a wide range of variables, including economic indicators, trade policies, and technological advancements.

4

What are some typical annual energy costs and electricity consumption figures, for a 12nm logic chip plant manufacturing 20000 wafers a month, and with 250 chips derived from each wafer?

ChatGPT

Estimating the annual energy costs and electricity consumption for a semiconductor manufacturing plant, specifically for producing 12nm logic chips at a rate of 20,000 wafers per month with 250 chips derived from each wafer, involves several variables. These include the specific energy efficiency of the manufacturing equipment, local electricity rates, and additional energy needs beyond the direct manufacturing process (e.g., cleanroom environmental controls, lighting, and office spaces). However, I can provide a general framework to estimate these figures.

Electricity Consumption Estimation:

1. **Manufacturing Process:** Advanced semiconductor manufacturing, particularly at nodes like 12nm, is energy-intensive due to the complexity of the processes involved (e.g., lithography, etching, chemical vapor deposition).
2. **Cleanroom Environment:** Semiconductor fabs require controlled environments with strict temperature and humidity levels, necessitating significant HVAC energy use.
3. **Support Facilities:** Other plant operations, including water purification systems and exhaust treatment systems, also consume energy.

Given the above, let's make some broad assumptions for a ballpark estimation:

- **Average Energy Use:** It's challenging to pinpoint exact figures without specific details on machinery and operational efficiencies. However, literature suggests that the energy consumption can be several megawatt-hours (MWh) per wafer. For this example, let's assume an average consumption of 0.25 MWh per wafer, which is within the range reported for advanced nodes but on the lower end to account for improvements in energy efficiency.
- **Total Monthly Energy Consumption:** For 20,000 wafers, this equates to 5,000 MWh per month.

- **Annual Energy Consumption:** Multiplying by 12 months gives 60,000 MWh annually.

Energy Cost Estimation:

The cost of electricity can vary widely depending on the geographical location of the plant. For simplicity, let's use an average industrial electricity rate of \$0.10 per kilowatt-hour (kWh), recognizing that rates can be significantly higher or lower.

- **Annual Energy Costs:** At this rate, the cost for 60,000 MWh (or 60 million kWh) would be \$6 million annually.

Important Considerations:

- This is a simplistic model and actual consumption and costs could be higher based on factors like plant design, the specific equipment used, and local electricity prices.
- Energy efficiency measures, such as waste heat recovery and the use of renewable energy sources, can significantly impact these figures.
- The assumption of 0.25 MWh per wafer is quite generic; specific processes and equipment efficiency can lead to wide variances from this figure.

For accurate assessments, details from equipment manufacturers, utility providers, and specific plant operational plans are necessary.

4

What are some typical annual personnel headcount figures and annual labor costs, for a 12nm logic chip plant manufacturing 20000 wafers a month, at \$60,000 average wage per employee?