Financial Resources and Technology to Transition to 450mm Semiconductor Wafer Foundries

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Abstract

Financial models that can be applied by management to build giant wafer foundries to manufacture low cost semiconductor products are demonstrated. This advanced semiconductor technology will likely drive a new frontier called the Internet of Everything, an expected $14 trillion market that will likely contribute to global positive social change.

Problem

The 2011 executive summary for the International Technology Roadmap for Semiconductors (ITRS) described a lack of financial models to provide flexible real options for management to operate next generation 450mm semiconductor wafer foundries spanning from R&D to commercialization. The European Commission Vice-President, Neelie Kroes stated the problem was a lack of wise investment tools to build and operate next generation wafer foundries. Real option models to enable wise investment decision making to conserve limited financial resources, to plan, to build, and to operate next generation 450mm wafer foundries did not exist in literature.

Purpose

The study may be the first to demonstrate an integrated real option platform to assist management to make wise investment decisions to invest, construct, and operate future 450mm wafer foundries in America and Europe. The real option platform was comprised of several three-stage, 10-year real options models that provide flexible options to emulate production capacity expansion and contraction, deferring an investment, or to abandon the project with a goal to realize the greatest NPV and to select the best business strategy. This study may be the first to present a new finance approach using the response surface methods, specifically the Box-Behnken design to develop inferential models that yield optimal solutions as an alternative to performing Monte Carlo simulations.

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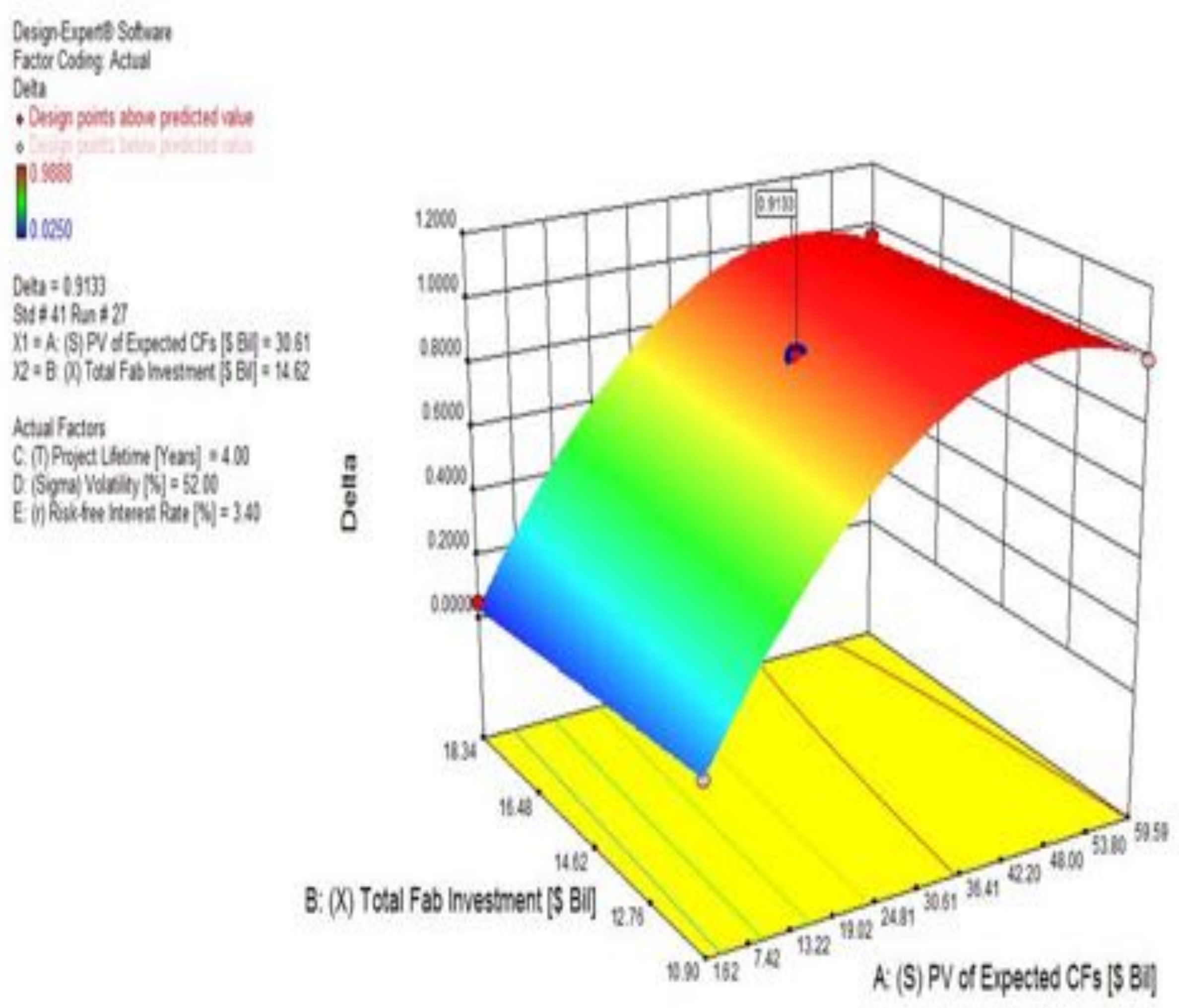
Relevant Literature

The literature review began with a source material study on the current status and problems to transition to future 450mm wafer foundries. Next, the literature review had focused on the theoretical framework which consisted of the Black-Scholes option pricing model, Moore's second law, and competitive game strategy theories, specifically the Nash equilibrium. The theoretical framework was based on the Nobel Prize winning Black-Scholes option pricing model which was originally developed for the futures market and then extended to solve real options, specifically European and American call and put options.

Research Questions

The first four research questions had focused on determining the highest NPV for next generation 450mm foundries in America and Europe. To solve these research questions, real options to expand production capacity, to contract production capacity, to defer an investment, and to abandon the project were developed. The last three research questions had focused on the determination of three real option sensitivity parameters, delta, vega, and theta using response surface methods as shown by Figure 1.



Procedures

An original structured survey instrument was designed based on the need to collect quantitative data to solve the first four research questions. The survey was limited to 23 questions, the first 11 questions had focused on construction of a pilot foundry and the remainder had focused on ramping-up a production foundry. The survey developed for the Americans was based on dollars, while the survey developed for the Europeans was based on euros. To design the best scale for two survey questions, Moore's second law equation was applied to determine the annual theoretical wafer foundry investment cost.

Data Analysis

Descriptive statistics was performed to evaluate central tendency and the data was presented using comparative box-plots. Data was applied in a discounted cash flow analysis, closed-form equations, and binominal lattices to determine key dependent variables before performing hypothesis testing using a paired-difference test for two data sets. Inferential statistics consisted of 18 second-order regression models with a Taylor Series expansion form for five independent variables to determine foundry operation to yield the greatest NPV performance. Predictions for each research question were tabulated and contour plots and three dimensional surface plots illustrated optimal foundry operation.

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Findings

Based on the findings for the seven research questions, this study found future American 450mm foundries with smaller capacity of 37,717 wafer starts per month (WSPM) will yield greater NPV in comparison to European foundries having greater capacity of 40,217 WSPM. This study found American 450mm wafer foundries will likely cost $14.6 billion while larger European foundries will likely cost $17.8 billion. This study found American 450mm foundries will likely operate for 18 years while European 450mm foundries will likely operate for 17 years. Finally, both foundries will likely reach commercialization by 2019 just in time to manufacture advanced semiconductor products for the Internet of Everything era by 2020.

Limitations

The key limitation was not performing a realistic net present analysis using the capital asset pricing model (CAPM) and a cash flow analysis using the appropriate discount rate, corporate tax rate, and other liabilities. These factors were ignored with intent to focus on the development of the four real options using two constructs. The Black-Scholes option pricing model and the Nash equilibrium were applied and conclusions were drawn. This may have been another limitation since these theories were not tested. It was believed these Nobel Prize theories were accurate since they most likely have been scrutinized by many researchers.

Conclusions

The Nash equilibrium which describes a rational cooperative game strategy will likely exist. As leaders, the American fab management operating smaller capacity 450mm foundries will likely manufacture premium processors, and will select the differentiation business strategy. As followers, European fab management with their rational cooperative mindset will likely build larger capacity foundries, will likely select the cost leadership strategy to manufacture commodity memories and sensors, and will likely achieve a 20% market share. Real option models and response surface methods were demonstrated to solve complex finance problems that support wise investment decision making.

Social Change Implications

This study describes how management can apply real options to operate future 450mm semiconductor foundries. Products manufactured in these foundries in 2019 are expected to drive the Internet of Everything by 2020. This new frontier is expected to improve the quality of life for societies around the globe with ICT, medical applications, and transportation safety. Advanced semiconductors will be needed to develop smart cities, smart buildings, smart farms, smart grids, and smart infrastructures. Semiconductors will be needed to produce novel medical applications such as silicon retina chips to restore vision to blind patients, bio-lab sensors to detect pathogens that cause diseases and viruses such as HIV/AIDS, to analyze cells for cancer detection, to perform Big Data analytic decision making and augmented reality for autonomous vehicles and robotics.

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