A Multi-Regional Model of the Development in Technology Industries

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ABSTRACT

Forecasting the production of technological development and manufacturing is important to managers, entrepreneurs, governments and others. A marketing strategy can be much more effective with an understanding of technological development, manufacturing and market projection analysis.

This paper aims to propose a System Dynamics model for the semiconductor industry in multi-regions, such as Japan, United States of America, and South Korea. We also tried applying this system to the digital camera industry. System Dynamics is a method for making educated predictions about future market trends which can aid businesses in their attempt to construct responses to a variety of possible scenarios. Therefore, the structure of the entire system is understood in a quantitative way, and the future can be forecasted. We constructed the model by dividing it into four sectors; the technological development sector, the demand sector, the manufacturing capability sector, and the production sector to calculate production for semiconductor industry. The model for the digital camera industry is divided into three parts as follows: the technological development sector, the demand sector, and the shipment sector which calculates the shipping volume.

The System Dynamics model was found to be capable of providing predictions for two technology industries; semiconductors and digital cameras. Further, the system Dynamics method of analysis enables businesses to set policies based upon the results discovered from the manipulation of various market scenarios.

Keywords: System Dynamics (SD), STELLA, demand forecasting, semiconductor, policy

1. INTRODUCTION

The reason we selected the semiconductor industry is stated below. The first invention of a semiconductor was the transistor which was made by Bell Labs in 1948. Since then the level of performance has dramatically improved**.** The products that include semiconductors are changing and increasing in number.

In the beginning, they were only utilized in transistorized calculators. However PCs, digital cameras, DVDs, plasma TVs, car navigation systems, cell phones and many other products now use semiconductors. The semiconductor industry developed on a grand scale. Initially, the Japanese semiconductor industry had 53% of the global market share in 1989, and the top three companies in the world were Japanese. These days, however, Japanese companies have around 20% of the global market share. While the United States of America has gained power rapidly since 1993.

In addition, South Korea is steadily expanding its global market share. However, the Japanese semiconductor industry could be reawakened with digital appliances. Also, the semiconductor's performance is developing dramatically. According to Moore's law, the integration of the semiconductor will double in 18 to 24 months. In the 1950s, there were only 4Kilo byte memory chips, but now the average personal computers is equipped with at least 256Mega bytes of memory, and several Giga bytes memory chips for mainframe computers. The semiconductor industry is developing exponentially, and the global share order often changes, therefore we selected this industry.

The second area of technology discussed in this paper, digital cameras, was put on the market by Casio Computer in 1995. The spread of the personal computer in turn gave rise to the production of the digital camera sales. In 2002, the production of digital camera surpassed the film type camera. The shift from the film type camera to the digital camera happened rapidly in Europe and America. Although there are regional differences in the amount of digital camera sales, the percentage of sales has increased in Europe and America. Japanese companies such as Sony, Canon Inc.., and Olympus maintain 90 percent

of the world share of digital camera sales. However, in the future, companies from other countries could challenge the Japanese market domination of digital cameras, around the globe.

2. SYSTEM DYNAMICS MODELING FOR SEMICONDUCTOR INDUSTRY

STELLA, a System Dynamics software program is used because the connections between various elements can be expressed visually and a given time series can be analyzed. DRAM (Dynamic Random Access Memory) first came to market in 1970 so we constructed out model to begin in that year. In this research, the target areas are Japan, the United States of America (U.S.A) and South Korea. This model consists of four sectors which are "Technological development," "Manufacturing capability," "Demand," and "Production." Each sector has relationship, as shown in Fig.1.

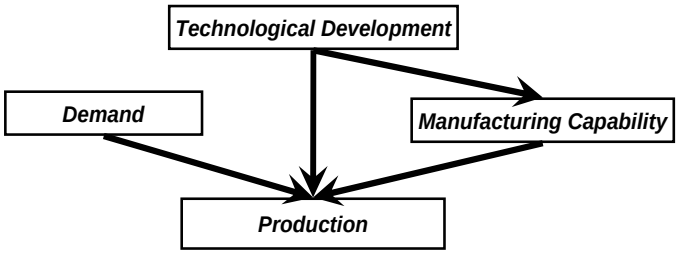

Fig.1. Relation of each sector

2.1 Technology development sector

We envisioned three types of semiconductors for this model, which are them Tech 1, Tech 2 and Tech 3. Development is reflected as the symbol progress from Tech 1 to Tech 3. We consider Tech1 as memory, Tech2 as CPU(Central Processing Unit), Tech3 as System LSI(Large-scale Integration). In this research, we draw upon Moore's law(1) which states that the integration of the semicondutor will double in from 18 to 24 month and silicon cycle(2) which suggests that the semiconductor industry's economic cycle is about four years.

$$D(t) = a * 2^{t} \qquad (1)$$

D(t) : Demelopment level, *a=D(0)* : Initial setting

$$SC(t) = 1 + 0.25 * \mathrm{Sin}\ (2\pi(t/4)) \qquad (2)$$

SC(t) : silicon cycle

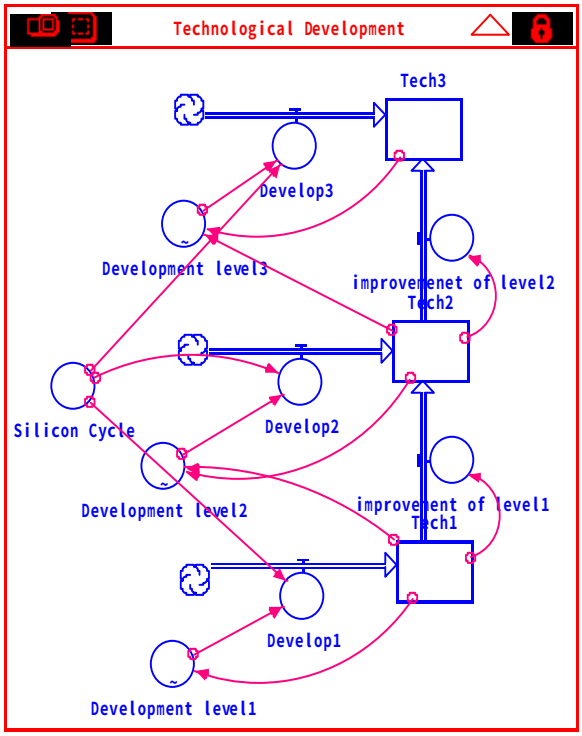

Fig.2. Techological Developmetn model

2.2 Manufacturing capability sector

In this sector, we draw upon Rock's law(3), which states that the construsction cost of semiconductor factory doubles every four years. This sector's model is connected with "Technology development" sector's model. Each manufacturing ability reacts to the degree of development within each Tech1, Tech2. Tech3.

$$FC\ (t) = c * 2^{t/4} \qquad (3)$$

FC(t) : Construction of factory *c* : initial setting

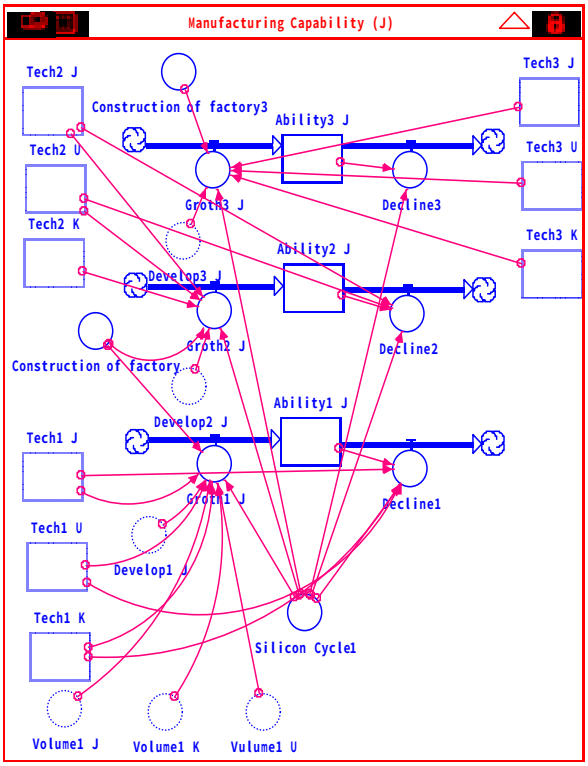

Fig.3. Manufacturing Capability

2.3 Demand sector

We don't have accurate demand data about semiconductors, therefore we assumed that the demand would follow the logistic curve. See equation(4). In this sector, the volume of each demand is variable by changing the Ultimate and Parameter(ref. Fig4). In the result we can simulate variours kinds of demends.

$$De(t) = K/1 + be^{-at} \qquad (4)$$

K: Ultimate a,b : Parameter

However, we were fixed each demand to make basic model. Each demand function for Tech 1,Tech 2 and tech 3 is as follows:

$$De1(t) = (4000/1 + 41.75e^{-0.307t}) + 2000 \qquad (5)$$

$$De2(t) = 8248/1 + 45.54e^{-0.347(t-8)} \qquad (6)$$

$$De3(t) = 9000/1 + 50e^{-0.356(t-22)} \qquad (7)$$

$De1(t), De2(t), De3(t)$: Demand

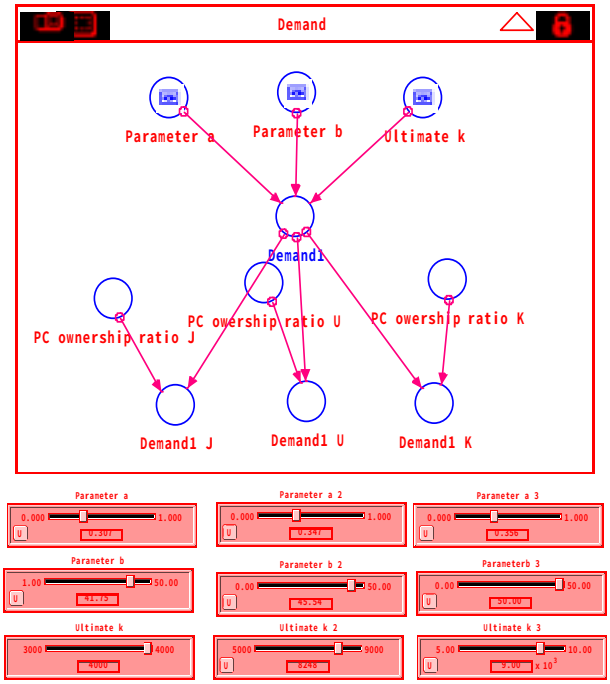

Fig.4. Demand model

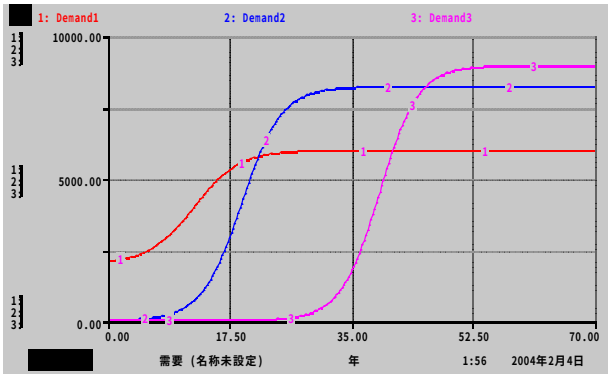

Fig.5. Example of demand

2.4 Production sector

In this model, we configured the compared value between salable quantities and producible quantities to work out each country's production. Producible quantities are the value of manufacturing ability, and salable quantities are under the influence of the technical gap between the countries and are calculated on the basis of product demand and the silicon cycle.

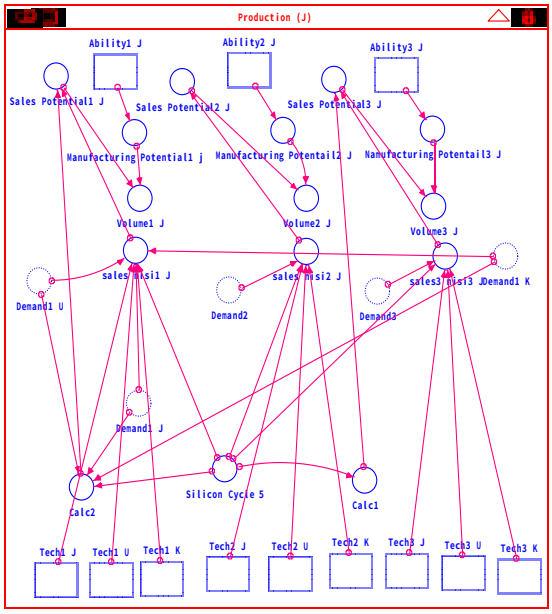

Fig.6. Production

3. ANALYSIS AND DISCUSSION

3.1 Construction of basic model

In "Technology development" and "Manufacturing ability" sectors, the initial setting of Tech 1's technology development for Japan and South Korea are set at 0, but for the U.S.A. it was set at 1000, because the U.S.A. developed and launched DRAM in 1970. We also treated countries differently with regard to Moore's law. For Japan, we estimated the development level to double every one year just for the first ten years. On the other hand, for the U.S.A. and South Korea, we set it for every two years. Then we set the condition that the level of technology in Japan would overtake the level of technology in America. Moreover, Japanese engineers contributed in part to the rise of South Korean semiconductor's technology. Therefore we determinded that Korean Tech 1 received some technology from Japanese Tech 1. Also Korean Tech 3 recieved some technology from Japanese Tech 3, because of the "IT initiative between Japan and Korea," which was enacted in 2000.

3.2 Comparison of simulation output with actual value

To estimate the degree of precision, we compared our model output with actual value. The actual value is DRAM's global share, which was investigated by Gartner Japan from the Ministry of Economy Trade and Industry. Our model result shows each country's share of Tech 1.

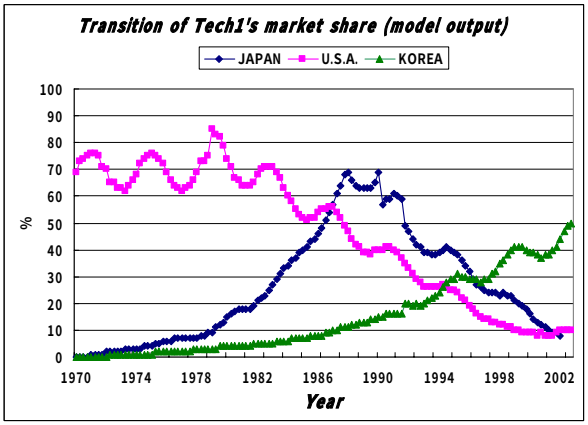

Fig.7. Transition of Tech1's market share (model output)

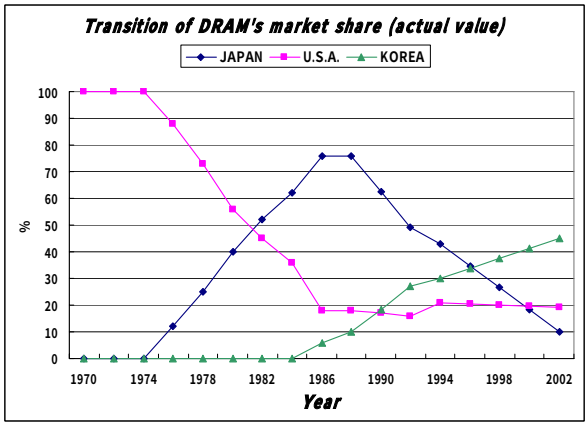

Fig.8. Transition of DRAM's market share (actual value)

It was judged that there was validity because a similar transition was seen when the graph was compared on some levels.

3.3 Simulation

With this model, we can try various simulations by establishing the prior conditions and certain scenarios. Then we may propose some policies to maintain the share or overtake competitors. We can easly change demand. So we could examine low demand or high demand version. If the international division of labor accelerates, we also could simulate that condision.

For example, we can hypothecate international division of labor. To be more precise we projected that the U.S.A. would concentrate on "CPU" production and South Korea would focus on the produciton of "Memory " to ensure the global market share, so they let the development of system LSI slide as a prior condition.

In addition, we created other scenarios. For instance, it is projected that Japan will concentrate on the development of system LSI in the above-mentioned condition. The simulation result is shown as follows.

➢ Scenario1

U.S.A. and South Korea lower the development power of Tech3 to concentrate on the each field which they are good at.

➢ Scenario2

Japan concentrates on Tech3 instead of Tech1 and Tech2, while set in Scenario2.

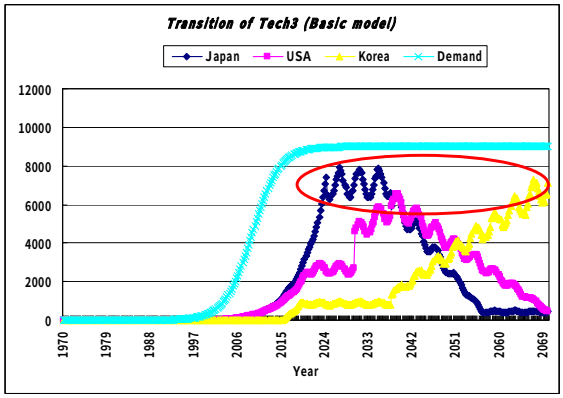

Fig.9. Transition of Tech3 (Basic model)

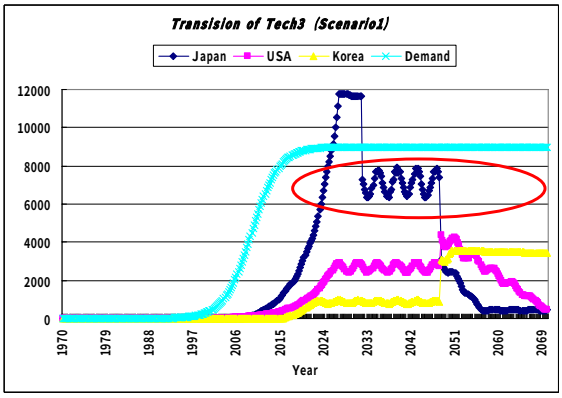

Fig.10. Transition of Tech3 (Scenario1 model)

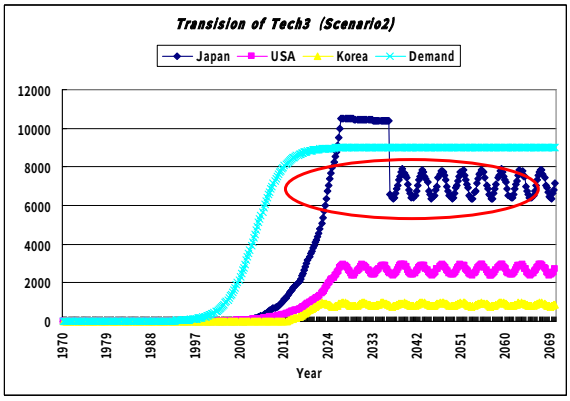

Fig.11. Transition of Tech3 (Scenario2 model)

In this model, the amount of producible quantities will increase rapidly when the development level greatly exceeds that of the other counties. Therefore, productions exceed the demand in Scenario1 and Scenario2 model. As a result, we could consider the investment for Tech3.

As observed above, the case that cannot experiment in the real world can be considered. We think that the ideal way of international cooperation and change of demand can be simulated and considered.

4. SYSTEM DYNAMICS MODELING FOR DIGITAL CAMERA INDUSTRY

This model was constructed with a similar idea to the model explained above and applied to the digital camera industry. In 2002, the production of digital camera surpassed the film type cameras. This occured in part because of the spread of personal computers. Furthermore, it is likely that the demand for digital cameras will continue to have prosperous growth for some time. Currently, Japanese manufactures control around 90% the global market share.

Consequently, this application we constructed aims to predict shipment of the digital cameras which are made in Japan to “Japan”, “Europe”, “North America” and “the other regions.” This model consisted roughly of three sectors, which are “Technological development,” “Demand,” and “Shipment.” Each sector’s relationship is not the same as the previous model. In the previous model, the “Demand” sector was independent, but in this model, we made relation as Fig.4. This model could also be used for various simulations. For example, it might be the case that a foreign company grows by leaps and bounds, or the digital device, mobile-phone or memory with camera spreads.

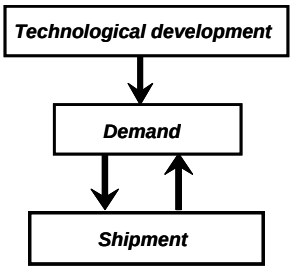

Fig.12. Relation of each sector

Although previous model’s “Demand” sector was not influenced by any sectors, in this application model’s “Demand” sector is influenced by both of “Technological development” sector and “Shipment” sector. We assumed that digital camera’s development, for example, capability of digital image and memory, will make the demand increase. Therefore, when the amount of technology became a fixed number in the

"Technological development" sector, the demand is influenced.

And the demand is also influenced by amount of shipment. The demand decreases when the rate of digital camera possession for Japan, Europe and North America population become 20%, in case for the others population become 2.5% by total amount of shipments.

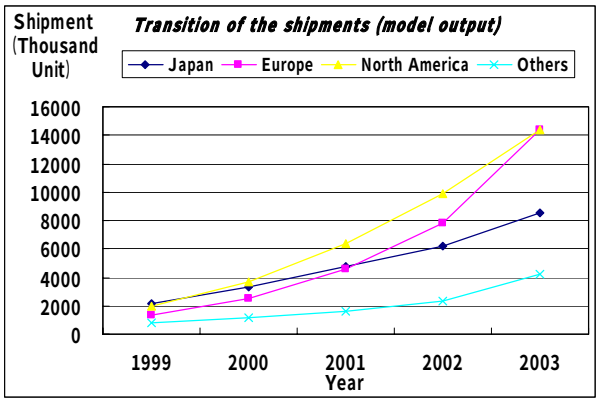

Fig.13. Transition of the shipments (model output)

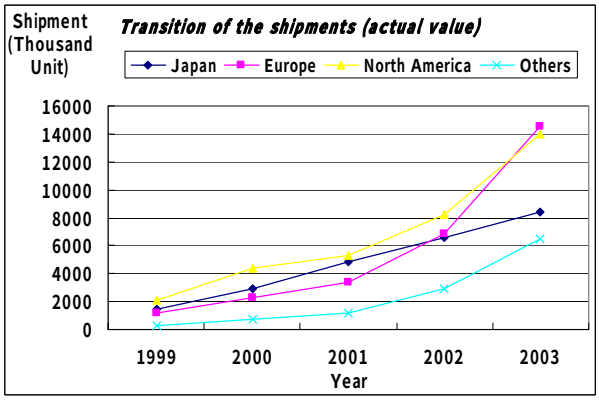

Fig.14. Transition of the shipments (actual value)

A similar transition was seen when the graph was compared on some levels. Furthermore, each correlation coefficient between the actual values and the model outputs is over 0.98. Therefore, It was judged that there was validity.

Table1. correlation coefficients of each region

	Japan	Europe	North America	Others
Correlation coefficient	0.993	0.994	0.984	0.995

4.1 Simulation

We considered the influence of foreign companies as Scenario1 and the digital devices, such as mobile-phone for the camera spreads as Scenario2. Both simulations span a fifty-year timeframe from 1995 to 2020.

➢ Scenario1

Some American companies grow rapidly in three years in the future. As a result, Japanese company's demand decreases 20% in the Japanese and European markets, 50% in American markets and 30% in the others markets.

➢ Scenario2

Digital devices start to influences when each demand is highest. As a result, Japanese company's demand decreases 50% in Japanese market, 30% in the American, European and the other markets.

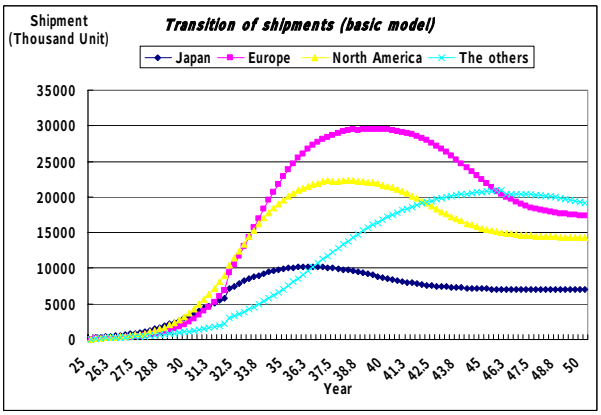

Fig.15. Transition of the shipments (basic model)

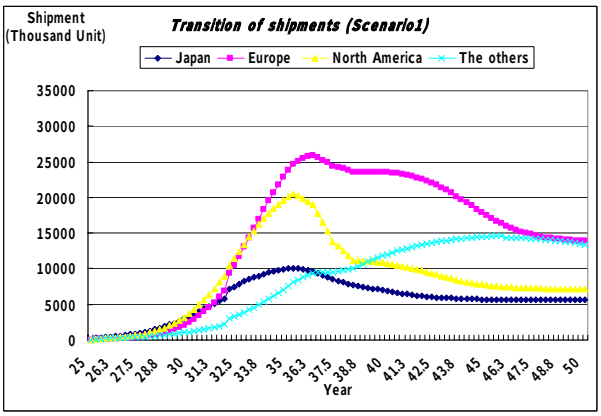

Fig.16. Transition of the shipments (Scenario1)

The total number of shipments is 1,210,953,000 in the basic model. In contrast, it is 957,266,000 in Scenario1, it decreases 21%.

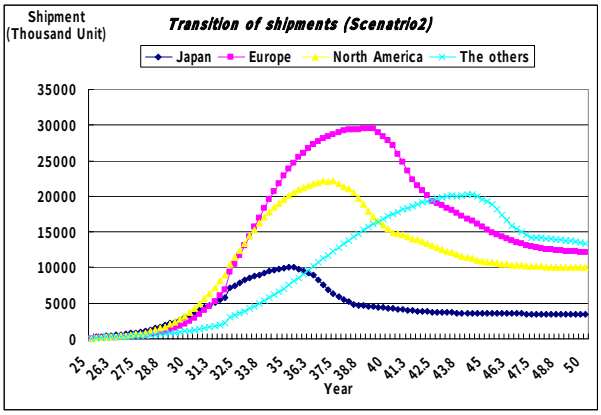

Fig.17. Transition of the shipments (Scenario2)

The total number of shipments is 1,016,402,000 in the Scenario2. It decreases 16% compared with basic model.

4.2 Discussion

In Scenario1, some American companies will grow rapidly over the next three years, because even though Japanese Companies now hold the top three positions in the world market, an American company in fourth place and they could move up. In the simulation, Japanese companies lost some of the American market share. However, some companies may be more competitive than the Japanese companies. Therefore the Japanese market might be invaded more than predicted.

In Snenario2, we considered the inclusion of the camera function to the digital device. Roughly three years have passed since the camera-equipped cell-phone was put on the market. Though a big influence has not been exerted yet, as more camera-equipped of these cell phone come equipped with high-resolution lenses, the markets will change. In this simulation, although we assumed that the demand will decrease 50%, we are concerned that the general consumer market for digital camera will be annihilation by phones equipped with super high resolution camera.

5. CONCLUSION

In this research, we could describe the process of development with System Dynamics. We paid notice to technological gap in multi-region, and targeted three types of semiconductors, and the digital camera industry. Then, we could examine the effect of policies or strategies by runing simulations.

The Japanese semiconductor industry has increased its the global market share of system LSI for digital appliances. However, the Japanese share may be reduced as had happened with “DRAM.” At first, the U.S.A. held the major market share, then Japan overtook them, but now South Korea holds the major share. Therefore, Japanese industry should concentrate on the development of system LSI.

For the digital camera industry, Japanese companies have held on to 90% of the global market share, but the other companies may grow from here on. Therefore to predict the demand would be more important, we should construct this kind of model with actual values.

The System Dynamics model was found to be capable of providing predictions for two technology industries; semiconductors and digital cameras. Further, the system Dynamics method of analysis enables businesses to set policies based upon the results discovered from the manipulation of various market scenarios. Moreover, this system enables support the policy decision by setting the scenario and simulating on some level.

Now we started to apply this system to the automoblile industry, because numerous auto companies are merging and reorganizing. Therefore to analize this industry can be effective.

REFERENCES

[1]. Po-Hsuan Hsu, Chi-Hsiu Wang, Joseph Z. Shyu, Hsiao-Cheng Yu, A Litterman BVAR approach for producion forecasting of technology industries, Technological Forecasting & Social Change 70(2002)67-82

[2]. K.Feldmann, H.Rottbauer, Electronically networked assembly systems fro global manufacturing, Journal of Materials Processing Technology 107(2000) 319-329