ISSN: 2288-7709 © 2020 KODISA & ICMA.
JEMM website: https://acoms.kisti.re.kr/jemm
Doi: http://dx.doi.org/10.20482/jemm.2023.11.1.31

Analysis of the Corporate Life Cycle using the Gompertz Model Focused on Korean Pharmaceutical Longevity Companies

Kyu-Jin CHOI[1], Kang-Sun LEE [2], Sung-Wook KANG [3], Dae-Myeong CHO [4]

Received: January 22, 2023. Revised: February 04, 2023. Accepted: February 05, 2023.

Abstract

Purpose: This study aims to figure out the characteristics of corporate life cycle and resource input in terms of the sustainability diagnosis of pharmaceutical companies in Korea. **Research design, data, and methodology:** Using the Gompertz model under the assumption that companies have finite resources, this study tries quantitative interpretation of life cycle and resource input pattern for longevity companies with 25 years of experience among 158 pharmaceutical companies listed on Korean stock market based on maturity of revenue. **Results:** The study found revenue maturity through Gompertz model was statistically correlated with enterprise value. According to the life cycle analysis, more than 95% of 59 pharmaceutical companies were in the growth and maturity phase and have an average life cycle of 88 years and an average remaining life of 52 years. Regarding maturity profile of resource input, maturity of employees was generally high more than 60% and this meant there was jobless growth in Korean pharmaceutical industry. **Conclusion:** This study demonstrated there is a high statistical correlation between the maturity of a company's resource input and its revenue and enterprise value. It is believed that these results could be utilized as a basis for high fidelity function that predict revenue and enterprise value based on resource input information.

Keywords: Corporate Life Cycle, Gompertz Model, Revenue Maturity, Enterprise Value

JEL Classification Code: C53, D15, L60

1. Introduction

Just as humans try to maintain a stable life in their environments, companies are also trying to continue their financial performance by interacting with their environments. In this sense of sustainability, much research has been done on corporate life expectancy. In particular, from the perspective of system theory that interprets organizations from the perspective of living organisms, companies also have the characteristics of a single life, so they have the property of protecting and protecting themselves (Aldrich, 1979).

The shorter the life cycle of a company's start-up phase, growth, maturity, and extinction, the higher the cost of social losses and the cost of individual losses. The development of free trade following the development of telecommunications

1 First Author, Ph.D. Researcher, Graduate School of Technology and Innovation Management, Hanyang University, Korea. Email: kilo2000@hanyang.ac.kr
2 Second Author, Ph.D. Researcher, Graduate School of Technology and Innovation Management, Hanyang University, Korea. Email: ksunlee@hanyang.ac.kr
3 Third Author, Ph.D. Student, Graduate School of Technology and Innovation Management, Hanyang University, Korea. Email: harison7@hanyang.ac.kr
4 Corresponding Author. Professor, Graduate School of Technology and Innovation Management, Hanyang University, Korea. Email:dmjo@hanyang.ac.kr

and transportation has placed companies in an infinite competition with each other, and without constant efforts for corporate sustainability, it is in a desperate situation that will perish. A company's life cycle research can help identify the characteristics of a company's preliminary and optimal response to the situation at each stage by identifying the characteristics of each stage that disappears from its start-up (Lippitt & Schmidt, 1967).

Prior corporate life cycle studies have defined and determined the life cycle of an enterprise by measuring the relative ranking of variables that measure the life cycle under the same distribution assumption (Anthony & Ramesh, 1992).

This study aims to diagnose a company's life cycle in a direct and quantitative manner by substituting a company's sales amount using the Gompertz model based on the assumption that companies have predetermined resources and follow it. Through the Gompertz model, it aims to contribute to the timely decision-making of a company's CEO for the sustainability of the company by measuring the life span of a company mathematically and identifying the stages it faces.

Meanwhile, this study focuses on Korean pharmaceutical industry. This industry doesn't have policy support, such as government subsidies or tax benefits, the bio sector has maintained a completely free competition system from the beginning of the industry, focusing on small and medium-sized companies. Among the listed pharmaceutical companies that have survived through such free competition and represented the Korean pharmaceutical industry, 59 companies with more than 25 years of experience have been selected as research subjects.

This study aims to substantially diagnose of Korean pharmaceutical companies by quantifying the current state (age) and remaining life expectancy of the company. By analyzing resource input patterns of employees, tangible assets, and intangible asset inputs throughout the company's life cycle, it aims to diagnose and predict the company's future investment and employment inducement capacity.

2. Literature Review

Based on the similarity of life patterns between life and companies, research has been conducted to explain the economic phenomena of companies as characteristics of life, and further research has been conducted by establishing a life cycle theory of products, companies, and industries.

2.1. Analogy Between Organism and Economy

The view that all forms of organizations formed through humans are considered and interpreted as a form of life is called system theory. This is based on biology, where organisms are studied. Thus, it is an approach that interprets and analyzes evolution, cell theory, homeostasis, and genes, which are the main concepts in biology, as environmental adaptation, growth, and development of human organization, and is widely applied to research on organizational characteristics (Hannan & Freeman, 1989).

Such theory-based research makes the principles under which various human organizations operate more practically identifiable and provides new perspectives and implications for the study of organizational characteristics. A company is an entity that generates revenue by planning and providing services and products. It can be recognized as an organism that has a life path of birth, growth, and death (Aldrich, 1999).

In addition to the theory of systems, complexity theory, which focuses on the interaction of the components that make up the economic system, has emerged. Complexity theory has attempted to interpret industrial and corporate development and growth from the perspective of self-organization theory. Self-organization theory refers to the optimization of a system or principal for one's own survival in a creative way without the influence of the external environment (Manson, 2001).

When nutrients are insufficient, tens of thousands of fungal fungi begin to move at once, gathering, and, at some point, forming a cohesion to form an organism to minimize the basic metabolic rate. When environment improves, it can be seen that it is dispersed into multiple single-celled organisms again. Hirschleifer (1978) describe**d** similarities in competitive behavior in life and economic systems, while ecologists Rapport and Turner (1977) describe**d** the community of life by comparing it to production and consumer behavior. This emphasiz**ed** the fundamental similarity between economics and ecology. Peltonniemi (2005) regarded the basic operating principles of ecosystems as complex adaptation systems with similar characteristics to human enterprise ecosystems, and conducted research based on similarities between them.

2.2. Corporate Life Cycle Theory

Living organisms have a fairly repetitive and predictable growth stage and pattern from birth to death, which has the advantage of being able to clearly define the aging process and death from characteristics to death. Lippitt and Schmidt (1967) first advocated the theory of a corporate life cycle, and Adizes (1986) first published the life cycle, judging that if a corporate life cycle was used to define a stage of life cycle, it would provide a practical guide to interpret the company's risk.

The concept of the life cycle was based on the Boston Consulting Group's 1960s product phase based on market share and growth rates. The corporate life cycle was similarly based on age, growth rate, and size, followed by prior research that presented consistent characteristics step by step dividing them into three stages of introduction, maturity, and decline.

2.3. Prior Study on Corporate Life Cycle Theory

Anthony and Ramesh (1992) presented the life cycle as the company's revenue growth rate, dividend payout ratio, share of capital expenditure and the age of the company. As a similar study, Bens et al. (2002) used revenue growth, book-to-stock ratio, research and development and capital expenditure to diagnose the life cycle of an enterprise, while DeAngelo et al. (2006) determined that investment propensity would decrease from growth to decline, resulting in profit margins.

Dickinson (2011) defined a corporate life cycle as introductory, growing, maturing, revamping and declining periods using the cash flow characteristics of financial, investment and operating activities in its financial statements. The characteristics of the step-by-step pattern are determined by the negative or positive value of the status of each step's cash flow, which names the life cycle stage.

Table 1: The Stage of Corporate Life Cycle in the Study of Dickinson (2011)

Predicted Sign	1	2	3	4	5	6	7	8
	Introduction	Growth	Mature	Shake-out			Decline	
Cash flows from operating activities	-	+	+	-	+	+	-	-
Cash flows from investing activities	-	-	-	-	+	+	+	+
Cash flows from financing activities	+	+	-	-	+	-	+	-

Bellone et al. (2008) claimed that the determinant of survival in French manufacturing had a different effect depending on the age of the company. Companies note that they survived on how to respond to continuous deterioration in performance rather than on temporary losses. Industrial concentration and confusion have been shown to be much more affected by start-ups than by older companies. On the other hand, older and more stable companies continued to compete for survival in terms of profitability and production efficiency, while start-ups compete for in-market survival by innovative factors rather than production efficiency.

Menzel and Fornahl (2009) presented a life cycle analysis model for clusters of companies. The development of the cluster at each stage was influenced by the growth of individual entities and the diversity and heterogeneity of knowledge those individual entities have, as well as the number of employees.

Cefis and Marsili (2019) has worked on analyzing the good timing and bad timing of innovation and survival over the corporate life cycle. Companies that have pushed for innovation within two years of their start-ups enjoy a long-term survival premium during and after the crisis. The duration of this crisis phase and the premium effect after the crisis depended on the form of innovation. Innovation in technology brought more lasting premiums than non-technical ones.

Existing prior studies have shown that corporate life cycle theory has been conceptual and relatively analytical and lacks quantitative and direct demonstration of it. This study uses the Gompertz model under the assumption that a company has finite resources to quantitatively interpret and explain the life and age of a company based on the maturity of its representative company performance and revenue.

3. Research Method

3.1. Gompertz Model

The Gompertz model was started by Benjamin Gompertz (1779–1865), a British insurance account, and was used to describe a model of population growth. The characteristic of this model is the S-shaped function of the time series, which interprets the growth characteristics as the slowest at the start and end of a particular period. Just as increasing and decreasing population is determined by the limited environment and resources given by Gompertz, corporate growth has a given lifetime, such as people, plants, and markets, and corporate growth variables over life span can be considered normal.

The following solutions can be calculated using the Gompertz model.

$$\frac{dP}{dt} = r\,P\ln\left(\frac{K}{P}\right) \quad (1)$$

where, P = Population
t = Time elapsed
K=Environmental receptive capacity
r = Positive constant

The solution is

$$P(t) = Ke^{ce^{-rt}} = Ke^{\ln(\frac{P_0}{K})e^{-rt}} \quad (2)$$

$$P(t) = Ke^{\ln(\frac{P_0}{K})e^{-rt}} = Ka^{b^t} \quad (3)$$

where, $e^{\ln\left(\frac{P_0}{K}\right)} = a,\ \ e^{-rt} = b^t$

The Gompertz model has been used in a variety of ways, including predicting growth and death in people and animals, predicting revenue of new products, predicting tourism demand, forecasting potential market demand, and predicting movie demand (Domingues, 2012).

In the Gompertz model, the cumulative number of people P(t) is applied as cumulative revenue Y(t), with population growth being considered similar to revenue growth as the basic input for growth forecast. It is converted to $Y_t = K \cdot a^{b^t}$, When putting logs, it is converted to $\log Y = \log K + (\log a) \cdot b^t$.

where, Y_t : Cumulative revenue up to t period
b : Degree of diffusion 0<b<1
a : Initial market acceptance rate 0<a<1
t : Year
K: Total potential market

$Y_t = K \cdot a^{b^t}$ can be converted to modified formula over time like $Y_1 = K \cdot a^{b^1}$, $Y_2 = K \cdot a^{b^2}$, $Y_3 = K \cdot a^{b^3}$, When putting the Log, it is converted into $\log Y_1 = \log K + (\log a) \cdot b^1$, $\log Y_2 = \log K + (\log a) \cdot b^2$, $\log Y_3 = \log K + (\log a) \cdot b^3$ and then solve these three equations, can get formula as a below

$$b^n = \frac{\sum_3 \log Y - \sum_2 \log Y}{\sum_2 \log Y - \sum_1 \log Y} \tag{4}$$

$$\log a = \left(\sum_2 \log Y - \sum_1 \log Y\right) \frac{b-1}{(b^n-1)^2} \tag{5}$$

$$\log K = \frac{1}{n}\left[\sum_1 \log Y - \left(\frac{b^n-1}{b-1}\right) \log a\right. \tag{6}$$

Generally used in growth analysis prediction models, the Gompertz and logistic models have something in common in the S-shaped form, but the logistic model is symmetric about the inflection point, while the Gompertz model has asymmetric patterns around the inflection point. The model was originally designed to describe human mortality, but has been used in various fields, including market prediction of new products in marketing, prediction of fruit and fish growth in agriculture, growth of bacteria and tumors in medicine, and disease spread.

Tsai (2013) used Gompertz model to predict quarterly LCD TV shipments from Q1 to Q4 of 2009 and found that small TVs have high market penetration and large TVs have low market penetration.

Jha and Saha (2018) used the Bass, Gompertz and logistic growth models to interpret the spread of 2G to 4G in Germany, the United Kingdom, France, and Italy, and predicted 3G, 4G and 5G networks.

Tatro (2018) was able to predict tumor growth patterns according to a cell proliferation model utilizing the Gompertz model based on 20-year trace data for 250 breast cancer patients. By applying the Gompertz model to long-term studies, it was possible to predict tumor growth as a function of time and predict breast tumor growth rates.

Zardin et al. (2019) estimated the growth curve of a Brazilian fish named Niletilapias as a Gompertz model and examined the characteristics of growth differences between male and female genders.

Olukayode (2019) developed a mathematical scheme using an approach using the Gompertz model to solve the Nigerian population problem. This study demonstrated that this Scheme was numerically stable and highly convergent and showed that the numerical and general solutions of this method were approximately the same results, which was used for predicting population growth in Nigeria in advance.

Jha and Saha (2020) conducted a predictive study of the expansion of 3G and 4G mobile services in India and evaluated them using Bass, Norton-Bass, Gompertz, and logistic models. While the Bass model was sensitive to both 3G and 4G data, Gompertz and logistic models predicted that the spread of 4G is 6.1 times faster than 3G.

General solution of Gompertz model is

$$Y_t = K\, a^{b^t} \tag{3}$$

When t=0 in above formula, it is modified to $Y_0 = K\, a^{b^0} = Ka$

Therefore $a = \frac{Y_0}{K}$ is confirmed. Here is a represents the initial market acceptance of corporate revenue. When differentiating it with t, it is modified to $a^{b^t} \ln(a)\, b^t \ln(b) K$, by differentiating with t once again, it is modified to $a^{b^t} \ln(a)\, b^t \ln^2(b)(\ln(a)\, b^t + 1)K$. An inflection point appears at the time t at which formula is zero, and if it presents as a and b, it is shown below.

$$t = \frac{\ln\left(-\frac{1}{\ln(a)}\right)}{\ln(b)} \tag{7}$$

This indicates that as the value of b increases, the time t that occurs at the inflection point increases, and thus the survival period of the company gradually increases as the value of b increases. Conversely, if the value of b has a small value, the survival period of the company is shortened, which shows that the degree of diffusion of the company's revenue progresses faster. In the Gompertz model, K is inherently environmental stress, but in the corporate growth model, it represents a potential market or potential revenue.

This study uses the Gompertz model to analyze revenue maturity, diffusion, initial market acceptance, and potential market size, quantitatively calculate corporate life and residual life, analyze maturity patterns of input resources with revenue, and derive functions to predict revenue maturity and enterprise value maturity.

3.2. Research Data

Of the total 169 pharmaceutical companies in Korea, 59 company with more than 25 years of experience were selected. While semiconductors, automobiles, shipbuilding, and petrochemicals have become industrial-focused with national policy support, the pharmaceutical sector has maintained a completely free competition system since the early days of the industry, with academic research on long-lived companies in this environment.

KIS Value database platform of NICE (Korea's leading credit rating agency), extracted financial statement information and estimated enterprise value information such as revenue, employees, Capex (tangible assets) and capital from each of the 59 pharmaceutical-longest companies between 1996 and 2019.

The estimated enterprise value was based on the RIM (Residual Income Valuation Model), which is based on shareholder value. In other words, the enterprise value is primarily aimed at maximizing shareholder profit and therefore the estimated value of the company in this study used an additional revenue model (RIM) based on the dividend discount model (DDM) from the perspective of shareholder profit (Ohlson, 1995).

Shareholder's equity value
= Current amount of equity
+ present value of future excess profit

$$= \mathrm{Equity}_0 + \sum_{t=1}^{\infty} \frac{\text{excess profit}_1}{(1+r_e)^t} \quad (8)$$

where, r_e = rate of return required

The required return rate refers to the minimum required return to maintain the value of the equity capital raised by the company as an equity cost, which is the minimum return required by the new investment.

The reason why the 59 pharmaceutical longevity companies selected in this study were not applied with market capitalization was difficult to regularize due to the high volatility of investors' psychological factors in addition to financial performance.

The excess profit model is a model that uses accounting variables to assess the value of a company's shareholders' equity. This model can facilitate valuation compared to DCF models. The valuation of shareholder value is a theory that uses a dividend discount model to assess the value of a company's shareholder value. However, future dividends are related to future comprehensive income and equity book value, which are accounting variables. Where comprehensive income refers to net income plus other comprehensive income, such as those arising from the revaluation of an asset.

End-of-the-year equity capital increases with comprehensive income, while dividends decrease by that much.

Future dividends
= Future comprehensive income
– equivalent to future equity growth (9)

This relationship allows a company to derive an excess profit model from the dividend discount model (DDM) (Cziglerné, 2020; Jiang & Lee, 2005).

The RIM is derived from the dividend discount model (DDM), which increases the end-of-year equity capital and reduces the end-of-year equity capital for dividends.

Final Equity
= Initial Equity
+ Comprehensive Profit
– Net Dividend (10)

Net Dividend(DIV_t)
= Initial Equity(BV_{t-1})
+ Comprehensive Profit(X_t)
– Final Equity(BV_t) (11)

In DDM, dividends can be defined as net dividends, so if formula (11) is substituted for DDM:

Shareholder's Equity Value

$$= \frac{\mathrm{DIV}_1}{(1+r_e)} + \frac{\mathrm{DIV}_2}{(1+r_e)^2} + \ldots\ldots$$

$$= \frac{\mathrm{BV}_0 + \mathrm{X}_1 - \mathrm{BV}_1}{(1+r_e)} + \frac{\mathrm{BV}_1 + \mathrm{X}_2 - \mathrm{BV}_2}{(1+r_e)^2} + \quad (12)$$

Add r_e, BV_0 to the numerator of the next year in the right side above, and r_e, BV_1 to the numerator of the next two years. The formula can then be expressed as follows:

Shareholder's Equity Value

$$= \frac{(1+r_e)\,\mathrm{BV}_0 + \mathrm{X}_1 - r_e\,\mathrm{BV}_0}{(1+r_e)} - \frac{\mathrm{BV}_1}{(1+r_e)}$$

$$+ \frac{(1+r_e)\,\mathrm{BV}_1 + \mathrm{X}_2 - r_e\,\mathrm{BV}_1}{(1+r_e)^2} - \frac{\mathrm{BV}_2}{(1+r_e)^2} + \ldots$$

$$= \mathrm{BV}_0 + \frac{\mathrm{X}_1 - r_e\,\mathrm{BV}_0}{(1+r_e)} + \frac{\mathrm{X}_2 - r_e\,\mathrm{BV}_1}{(1+r_e)^2} - \frac{\mathrm{BV}_2}{(1+r_e)^2} + \quad (13)$$

$r_e\mathrm{BV}_2$, $r_e\mathrm{BV}_3$ …. for numerator of the next 3 years and 4 years. is added and arranged in the above manner, and (13) is the following RIM.

Suppose last term $\frac{BV_{\infty}}{(1+r_e)^{\infty}}$ converges to zero In formula (13),

Shareholder's Equity Value

$$= BV_0 + \sum_{t=1}^{\infty} \frac{X_t + r_e - BV_{t-1}}{(1+r_e)^t} \tag{14}$$

= Current amount of Equity
+ Present value of future excess profit

The formula (14) is presented for entities that do not have subsidiaries (Perek & Perek, 2012).

3.3. Research Scheme

Based on the actual database of NICE evaluation information (KIS Value1), the growth pattern was derived by substituting the corporate management data of 59 domestic long-lived pharmaceutical companies using Gompertz model, and the scheme of this study is shown below (Figure 1).

Input : KIS Value

Output: Revenue/Resources(Capex, Labor), Maturity(cumulative output for year t/K(potential revenue)

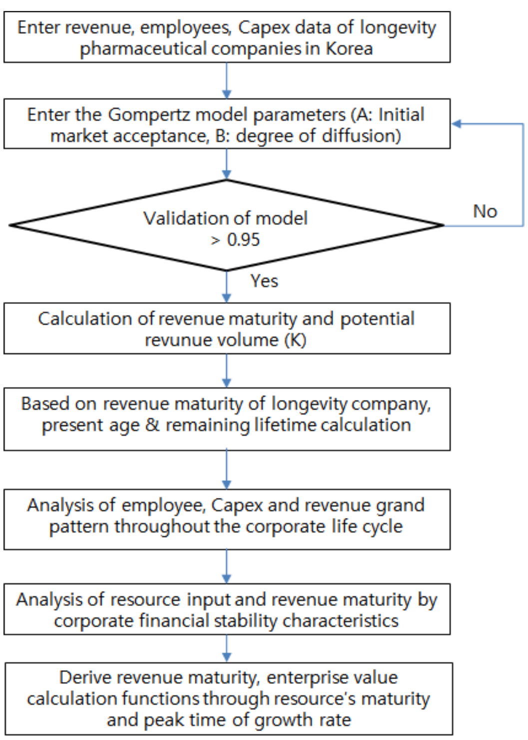

Figure 1: Research Scheme

4. Analysis and Results

4.1. Fits for Gompertz Model

To increase the accuracy of predictions on cumulative revenue, Root Mean Square Error (RMSE) yields variables K, a, and b, which can be minimal, and SST and SSE are calculated to verify the accuracy of the prediction model, and its ratio is obtained to verify the model suitability. Among the 59 Korean pharmaceutical longevity companies, Company No.1 showed 99.14% model fit with determinants, while the rest of the companies showed model fit at least 0.95 or higher. (Fig 2)

$$R^2 = 1 - \frac{SSE}{SST} = 0.9914$$

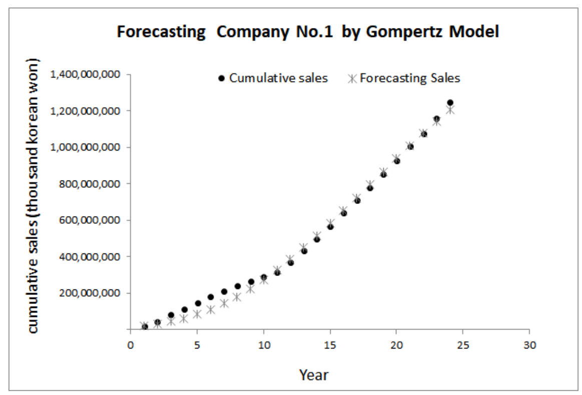

Figure 2: Gompertz Model Simulation, Accumulative Revenue Forecast

4.2. Analysis of Gompertz Analysis by Company

Through the analysis of Gompertz by companies based on cumulative revenue, it is possible to simultaneously interpret potential revenue (K), initial market acceptance (a), and degree of diffusion (b) at the same time. The average revenue maturity of domestic pharmaceutical longevity companies is 46.5%, and it is distributed from at least 20 percent to up to 70 percent, and the potential revenue are analyzed to be between at least 2 trillion won and 60 trillion won.

Table 2: Potential Revenue(K), Initial Market Acceptance(a), Degree of Diffusion(b) Revenue Maturity (%) Analysis Results

Company name	K(Thousand \) Market Potential	b	a	Maturity
No .1	2,135,301,504	0.9126	0.0059496	58.51%
No .2	12,042,555,475	0.8989	0.0060496	69.63%
No .3	4,693,935,779	0.9176	0.0023496	47.72%
No .4	5,868,294,851	0.9247	0.0009396	41.24%
No .5	1,801,281,990	0.9253	0.0084155	47.44%

Company name	K(Thousand \) Market Potential	b	a	Maturity
No .6	44,841,259,387	0.9477	0.0014155	16.59%
No .7	3,336,002,479	0.9059	0.0095155	65.38%
No .8	1,119,093,196	0.9248	0.0109516	48.09%
No .9	73,757,855,462	0.9419	0.0005316	16.32%
No .10	702,184,365	0.9168	0.0118555	60.25%
No .11	12,230,354,814	0.9401	0.0011355	22.41%
No .12	3,434,447,522	0.9258	0.0015301	37.49%
No .13	5,274,181,357	0.9343	0.0022355	32.03%
No .14	2,345,761,204	0.9149	0.0014355	46.46%
No .15	6,932,810,602	0.9449	0.0011755	17.46%
No .16	20,676,017,016	0.9456	0.0008201	16.33%
No .17	2,115,922,023	0.9010	0.0145545	73.93%
No .18	7,715,194,538	0.9190	0.0122355	57.19%
No .19	12,725,043,922	0.9510	0.0011355	12.63%
No .20	4,037,863,789	0.9390	0.0011355	23.73%
No .21	814,379,736	0.9190	0.0012355	41.45%
No .22	18,926,871,661	0.9356	0.0031355	31.06%
No .23	4,117,061,424	0.9010	0.0086355	69.67%
No .24	1,521,172,805	0.9287	0.0020994	36.93%
No .25	1,291,072,204	0.9153	0.0387955	69.52%
No .26	2,055,971,720	0.9207	0.0089355	52.46%
No .27	3,199,133,290	0.9091	0.0063555	58.19%
No .28	14,701,296,948	0.9404	0.0020136	22.94%
No .29	3,026,276,391	0.9155	0.0031936	52.13%
No .30	2,090,779,763	0.9317	0.0025355	32.10%
No .31	2,880,889,441	0.9354	0.0011355	24.83%
No .32	2,349,158,752	0.9325	0.0039926	35.50%
No .33	1,533,538,506	0.9158	0.0042926	51.91%
No .34	6,218,100,881	0.9078	0.0063926	59.25%
No .35	1,995,962,335	0.9203	0.0000426	25.27%
No .36	6,834,804,561	0.9304	0.0015228	31.68%
No .37	714,227,196	0.9037	0.0058196	67.80%
No .38	5,936,390,335	0.9298	0.0162202	50.43%
No .39	3,152,886,722	0.9354	0.0025920	30.27%
No .40	751,637,135	0.9233	0.0083396	51.91%
No .41	5,072,990,413	0.9146	0.0009104	45.98%
No .42	1,819,339,487	0.9036	0.0062396	63.67%
No .43	60,874,937,862	0.94	0.0021396	25.59%
No .44	5,704,276,294	0.9312	0.0011096	28.62%
No .45	5,971,307,624	0.8865	0.0082940	75.76%
No .46	1,886,905,847	0.8848	0.0133640	80.12%
No .47	4,475,439,248	0.9072	0.0199396	71.38%
No .48	986,503,030	0.9209	0.0090084	52.07%
No .49	1,791,162,858	0.9428	0.0018396	21.79%
No .50	1,202,431,506	0.9024	0.0047955	63.84%
No .51	850,627,050	0.9214	0.0064896	53.73%
No .52	638,706,317	0.8364	0.0087996	91.24%
No .53	5,279,619,877	0.972	0.0061996	7.60%
No .54	1,784,994,435	0.9236	0.0040396	45.68%
No .55	10,451,409,972	0.9095	0.0061596	61.56%
No .56	2,701,439,706	0.904	0.0077396	64.26%
No .57	3,302,486,525	0.8957	0.0165096	76.98%
No .58	3,057,275,841	0.916	0.0037496	51.28%
No .59	3,652,952,672	0.9133	0.0040496	56.39%

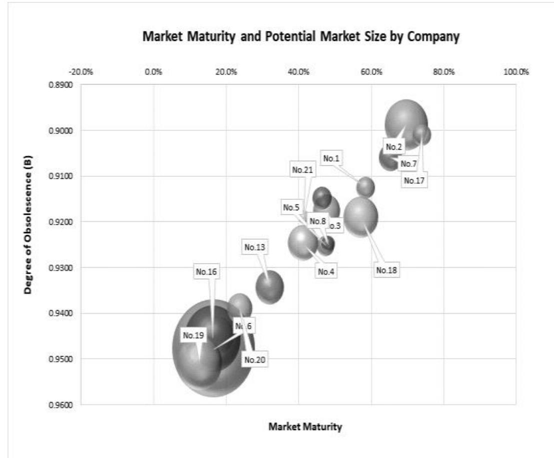

Figure 3: Potential Revenue(K), Initial Market Acceptance(a), Degree of Diffusion(b) Revenue Maturity (%) Analysis Results

The corporate life cycle was defined in formula (3) above until revenue reached 0.01% to 99%, and calculated by substituting it in the following manner:

$$0.99\ K = K \cdot a^{b^t} \tag{14}$$

$$0.0001\ K = K \cdot a^{b^t} \tag{15}$$

According to the results of this study, the average life cycle of Korean pharmaceutical longevity companies was 88 years and residual life span was 52 years, respectively. The life cycle distribution had a long overall life cycle of more than 70 years up to 120 years, and residual life was calculated from 20 years up to 100 years. That is, although long-lived, most of them still yield high residual life. Company life cycle applied the Rogers diffusion model of revenue maturity-based Introduction (up to 16%), Growth (16~49%), Maturity (50~84%) and Decline (above 84%).

Table 3: Accumulated Revenue Base, Pharmaceutical Company Life Cycle and Residual Life in 2000-2017 (unit: year)

Company name	Calculated Lifetime	Remaining Life	Company life cycle
No. 1	74.5	30.9	Maturity
No. 2	64.0	19.4	Maturity
No. 3	79.3	41.5	Growth
No. 4	87.1	51.2	Growth
No. 5	87.9	46.2	Growth
No. 6	126.9	105.9	Growth
No. 7	69.0	23.9	Maturity
No. 8	87.3	45.3	Growth
No. 9	114.0	95.4	Growth
No. 10	78.5	31.2	Maturity
No. 11	110.5	85.7	Growth

Company name	Calculated Lifetime	Remaining Life	Company life cycle
No. 12	88.4	55.3	Growth
No. 13	100.4	68.2	Growth
No. 14	76.7	41.0	Growth
No. 15	120.4	99.4	Growth
No. 16	121.8	102.0	Growth
No. 17	65.4	17.1	Maturity
No. 18	80.8	34.6	Maturity
No. 19	135.6	118.5	intro
No. 20	108.3	82.6	Growth
No. 21	80.8	47.3	Growth
No. 22	102.4	70.6	Growth
No. 23	65.5	19.9	Maturity
No. 24	92.1	58.1	Growth
No. 25	77.1	23.5	Maturity
No. 26	82.5	39.2	Maturity
No. 27	71.6	29.9	Maturity
No. 28	110.9	85.5	Growth
No. 29	77.2	37.0	Maturity
No. 30	96.5	65.5	Growth
No. 31	102.1	76.7	Growth
No. 32	97.5	62.9	Growth
No. 33	77.6	37.3	Maturity
No. 34	70.5	28.7	Maturity
No. 35	82.1	61.4	Growth
No. 36	94.6	64.6	Growth
No. 37	67.3	21.7	Maturity
No. 38	93.8	46.5	Maturity
No. 39	102.1	71.2	Growth
No. 40	85.5	41.1	Maturity
No. 41	76.4	41.3	Growth
No. 42	67.3	24.4	Maturity
No. 43	110.3	82.1	Growth
No. 44	95.7	68.3	Growth
No. 45	56.6	13.7	Maturity
No. 46	55.7	11.1	Maturity
No. 47	70.1	20.0	Maturity
No. 48	82.8	39.7	Maturity
No. 49	115.8	90.6	Growth
No. 50	66.4	24.0	Maturity
No. 51	83.3	38.5	Maturity
No. 52	38.2	3.3	Decline
No. 53	239.8	221.6	intro
No. 54	85.8	46.6	Growth
No. 55	71.9	27.6	Maturity
No. 56	67.6	24.1	Maturity
No. 57	61.9	14.3	Maturity
No. 58	77.7	37.9	Maturity
No. 59	75.2	32.8	Maturity

4.3 Corporate Life Cycle Stage Distribution

Korean longevity pharmaceutical companies with over 25 years of experience were classified into Introduction (up to 16%), Growth (16-50%), Maturity (51-84%) and Decline (above 84%) according to the application of the distribution ratio of Rogers technology based on revenue maturity. As a result, more than 95% of Korean pharmaceutical companies, including 28 out of 59 in the Growth phase and 28 in Maturity, confirmed the sustainability of the companies (Figure 4 & 5).

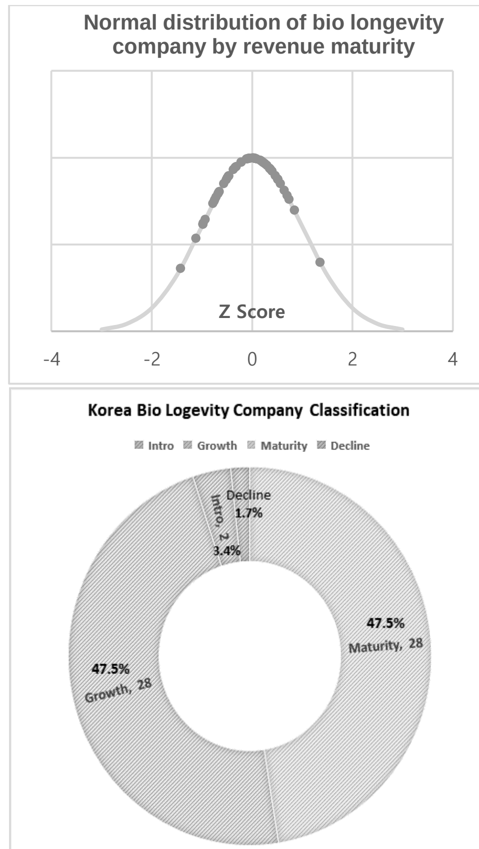

Figure 4: Life Cycle Stage Positioning for Longevity Pharmaceutical Companies Based on Revenue Maturity

In fact, even in the graph that analyzed distribution curves by normalizing revenue maturity of companies corresponding to each group of Introduction, Growth, Maturity, and Decline, we found that the distribution of corporate life of Korean pharmaceutical longevity companies was concentrated in the center of the Growth/Maturity curve.

4.4 Research on Resource Characteristics of Longevity Pharmaceutical Company

4.4.1 Analysis of Individual Company's Maturity Profile of Revenue, Employee, and Capex

The future patterns of the input of revenue and tangible resources (facility investment, manpower) can be predicted and presented through K, a and b derived from the analysis of Gompertz based on the revenue of each company. In the case of Company No. 1, maturity appeared in the order of employees, revenue, and Capex. Revenue maturity in 2020 was 70%, while employee maturity was predicted to be more than 80% and 60% of Capex (Figure 5).

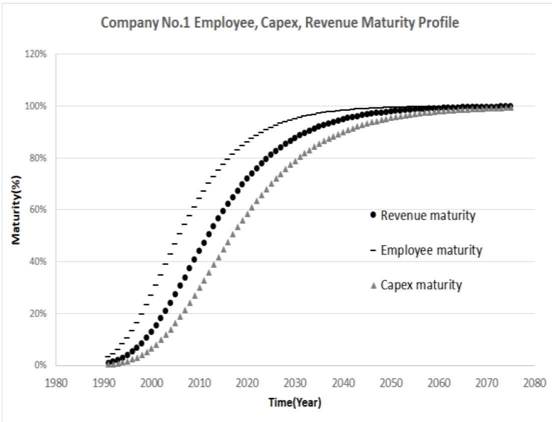

Figure 5: Company No.1's Employee, Capex, Revenue Maturity Profile

Figure 5's Profile can be used as a basis for viewing maturity patterns of input resources throughout the future life cycle and planning to ensure that there are no excessive or deficient distribution strategies for each future input resource.

In addition, it was analyzed that long-term pharmaceutical companies in Korea have a Grand Pattern, which precedes employee maturity and growth inflection points, followed by revenue maturity and growth inflection points, while Capex has various maturity and growth inflection points. This is estimated to appear as a mixture of specialized pharmaceutical businesses such as infectious disease vaccines followed by investment in tangible assets due to pre-orders and general pharmaceutical businesses in different aspects.

When the calculated Gompertz model is differentiated for time t, a formula of (7) is produced.

$$t = \frac{\ln(-\frac{1}{\ln(a)})}{\ln(b)} \tag{7}$$

For example, in Company No.1, the highest year of employee growth is t=12 years, the highest year of Capex growth is t=22 years and the highest year of revenue growth is t=19 years.

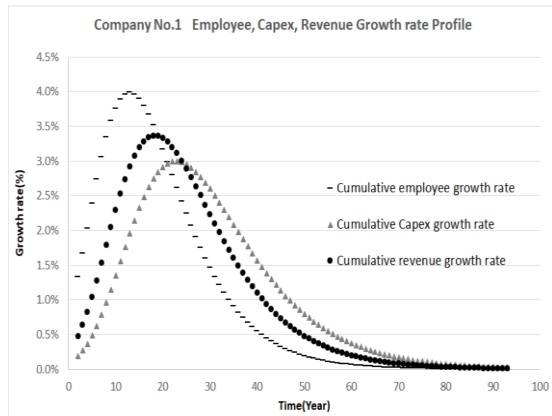

Figure 6: Company No.1's Employee, Capex, Revenue Growth Rate Profile

Maturity of Capex of Korean long-lived pharmaceutical companies ranged widely from 10% to 70% while maturity of employees was generally more than 60% in the Maturity stage of resource input.

Table 4: Revenue, Employees, Capex, Enterprise Value Maturity and Peak Time of Growth over 25 years

Company	Maturity (%)				Peak time of growth rate (year)			
	Revenue	Employee	Capex	Enterprise value	Revenue	Employee	Capex	Enterprise value
No .1	59%	77%	42%	39%	17.86	12.40	22.31	18.46
No .2	70%	80%	63%	69%	15.29	11.72	16.52	11.27
No .3	48%	56%	62%	57%	20.94	17.78	16.94	14.09
No .4	41%	30%	25%	5%	24.80	31.87	29.49	37.48
No .5	47%	70%	58%	53%	20.15	13.49	17.37	14.64
No .6	17%	59%	43%	47%	35.01	16.29	21.97	16.28
No .7	65%	77%	75%	71%	15.57	11.93	13.10	10.84
No .8	48%	66%	47%	N.A	19.28	13.91	20.57	N.A.
No .9	16%	15%	7%	36%	33.75	36.62	50.07	19.41
No .10	60%	78%	56%	43%	17.14	12.16	17.87	17.17
No .11	22%	34%	38%	30%	31.01	25.39	23.44	21.41
No .12	37%	66%	58%	71%	24.23	15.63	18.29	11.52
No .13	32%	63%	15%	4%	26.63	16.23	36.58	46.23
No .14	46%	65%	65%	52%	21.12	15.50	16.15	15.26
No .15	17%	69%	34%	4%	33.69	13.97	25.40	43.54
No .16	16%	32%	10%	26%	35.03	26.13	40.83	23.10
No .17	74%	79%	75%	86%	13.83	11.67	13.09	9.54

Company	Maturity (%)				Peak time of growth rate (year)			
	Revenue	Employee	Capex	Enterprise value	Revenue	Employee	Capex	Enterprise value
No .18	57%	83%	N.A.	54%	17.56	10.50	N.A.	14.60
No .19	13%	35%	17%	66%	38.06	24.37	34.50	13.17
No .20	24%	31%	32%	29%	30.39	26.74	25.89	21.62
No .21	41%	47%	70%	N.A	22.53	20.63	15.88	N.A.
No .22	31%	60%	34%	33%	26.31	16.58	24.92	20.41
No .23	70%	75%	48%	38%	14.96	12.55	19.97	18.74
No .24	37%	46%	30%	N.A	24.57	20.76	26.56	N.A.
No .25	70%	86%	66%	N.A	13.31	9.21	13.91	N.A.
No .26	52%	72%	59%	51%	18.77	12.99	17.60	15.37
No .27	58%	69%	74%	90%	17.01	14.03	14.01	7.74
No .28	23%	62%	44%	42%	29.69	15.74	21.13	17.58
No .29	52%	64%	72%	52%	19.80	15.69	14.54	14.94
No .30	32%	69%	54%	66%	25.29	13.94	18.36	11.91
No. 31	25%	66%	28%	30%	28.64	15.34	27.52	21.27
No. 32	36%	66%	10%	14%	24.44	15.02	43.43	28.82
No. 33	52%	61%	44%	42%	19.29	16.20	21.75	17.69
No. 34	59%	77%	42%	55%	16.75	12.48	22.27	13.73
No. 35	25%	26%	26%	15%	27.80	28.76	28.22	28.30
No. 36	32%	50%	39%	53%	25.93	19.41	23.28	14.83
No. 37	68%	80%	5%	N.A	16.17	10.46	55.90	N.A.
No. 38	50%	75%	50%	46%	19.47	11.89	19.04	16.96
No. 39	30%	72%	46%	N.A	26.71	13.64	21.10	N.A.
No. 40	52%	47%	25%	45%	19.63	20.05	30.01	15.74
No. 41	46%	42%	28%	23%	21.80	22.20	28.52	24.47
No. 42	64%	80%	69%	78%	16.03	11.38	15.74	10.13
No. 43	26%	66%	82%	53%	29.37	14.87	11.39	14.87
No. 44	29%	43%	6%	38%	26.91	21.87	54.21	18.66
No. 45	76%	75%	47%	67%	13.00	11.61	18.83	12.24
No. 46	80%	78%	73%	69%	11.95	11.70	14.33	11.70
No. 47	71%	88%	51%	27%	14.02	9.12	19.54	22.70
No. 48	52%	88%	66%	30%	18.82	9.17	15.55	20.95
No. 49	22%	59%	9%	35%	31.25	17.27	41.86	17.38
No. 50	64%	71%	50%	80%	16.31	13.76	20.33	9.56
No. 51	54%	55%	5%	44%	19.75	17.90	49.97	15.27
No. 52	91%	88%	85%	N.A	8.70	9.60	10.44	N.A.
No. 53	8%	31%	N.A.	N.A	57.17	27.99	N.A.	N.A.
No. 54	46%	66%	30%	N.A	21.46	14.97	27.35	N.A.
No. 55	62%	65%	60%	55%	17.15	15.07	16.52	14.31
No. 56	64%	84%	67%	25%	15.66	10.56	15.03	24.42
No. 57	77%	74%	70%	71%	12.82	12.49	14.56	10.57
No. 58	51%	30%	41%	50%	19.60	27.05	22.70	15.55
No. 59	56%	70%	30%	34%	18.81	14.10	26.60	18.90

While Korean pharmaceutical longevity companies are mostly in the growth and maturity stages of revenue, employees are distributed beyond the Maturity stage, showing that they are making jobless growth, suggesting that companies and governments should create new jobs by driving new growth engines into new products or convergence areas.

4.4.2. Resource Properties by Longevity Pharmaceutical Company Cluster

In order to analyze between the revenue maturity, employee maturity and Capex maturity, Korean pharmaceutical companies are divided into two clusters (Group 1: 10 times or more, Group 2 : 10 times or less compared with capital) by ratio of excess earnings to capital. average maturity gap between Capex & Employee with revenue in Group 1 is 10.8% and is 19.1% in Group 2. (Tabe5, Table 6)

t-Test in Table 7 demonstrates that average maturity gap between Group 1 and Group 2 are meaningful under 5% of confident level. This confirmed that in the case of business groups with sufficient profit surpluses, resource input is similar to the trend of revenue increase.

Table 5: Group 1 - Ten Times More Retained Earnings to Capital over 25 years (20 Companies)

Company	Maturity Gap between Revenue & Capex	Maturity Gap between Revenue & Employee	Company	Maturity Gap between Revenue & Capex	Maturity Gap between Revenue & Employee
No. 3	14.6%	8.1%	No. 28	21.2%	38.9%
No. 5	10.4%	22.9%	No. 31	3.3%	41.1%
No. 9	9.4%	1.2%	No. 33	8.4%	9.5%
No. 10	3.1%	17.6%	No. 35	0.9%	0.8%
No. 11	15.8%	11.5%	No. 36	7.1%	17.8%
No. 13	17.0%	22.3%	No. 41	20.8%	3.5%
No. 16	6.7%	15.8%	No. 46	6.7%	1.7%
No. 22	3.4%	28.7%	No. 49	12.5%	37.4%
No. 23	21.6%	5.5%	No. 55	1.5%	3.4%
No. 26	6.1%	19.6%	No. 59	26.3%	13.9%

Table 6: Group 2 - Ten Times Less Retained Earnings to Capital over 25 years (37 Companies)

Company	Maturity Gap between Revenue & Capex	Maturity Gap between Revenue & Employee	Company	Maturity Gap between Revenue & Capex	Maturity Gap between Revenue & Employee
No. 1	16.4%	18.1%	No. 34	16.8%	17.7%
No. 2	7.1%	0.1%	No. 37	71.2%	6.7%
No. 4	16.7%	19.1%	No. 38	0.0%	24.3%
No. 6	26.2%	42.7%	No. 39	15.0%	40.8%
No. 7	9.2%	11.8%	No. 40	27.3%	4.7%
No. 8	2.9%	17.6%	No. 42	4.4%	16.4%
No. 12	20.3%	28.5%	No. 44	22.1%	14.0%
No. 14	18.4%	18.2%	No. 45	24.8%	14.4%
No. 15	16.6%	51.8%	No. 47	20.0%	16.7%
No. 17	1.1%	4.7%	No. 48	13.0%	34.4%
No. 18	6.8%	18.8%	No. 50	13.6%	7.0%
No. 20	7.9%	6.9%	No. 51	49.9%	0.7%
No. 21	31.8%	9.0%	No. 52	5.9%	4.5%
No. 24	6.4%	9.0%	No. 53	117.3%	23.0%
No. 25	3.7%	16.4%	No. 54	15.8%	20.4%
No. 27	15.7%	11.1%	No. 56	2.3%	19.4%
No. 29	20.0%	11.9%	No. 57	6.6%	2.7%
No. 30	21.7%	37.3%	No. 58	10.3%	21.5%
No. 32	25.7%	30.5%			

Table 7: T-test for Average of Maturity Gap Capex & Employee with Revenue in Group 1 & 2

Statistics	Group 1	Group 2
Average	10.8%	19.1%
Variance	0.006	0.044
Num of observation	20	37
Hypothesis mean difference	0	
Degree of Freedom	54	
t Statistics	-2.212	
P(T<=t) One-sided test	0.015	
t Rejection One-sided test	1.673	
P(T<=t) Two-sided test	0.031	
t Rejection Two-sided test	2.005	

4.4.3. Correlation Analysis Between Enterprise Value and Revenue of Longevity Pharmaceutical Companies

Enterprise value maturity increases by 0.52 units when revenue maturity increases by 1 unit at a significant level of 1%. In addition, The peak time of Enterprise value growth rate increases by 0.47 units when the peak time of revenue growth rate increases by 1 unit at a significant level of 1%.

The statistical correlation between revenue-based maturity and enterprise value was proven, and this confirmed the logical validity of the corporate life cycle study based on revenue maturity.

Table 8: Regression Analysis between Enterprise Value Maturity (%) and Revenue Maturity (%)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	0.219	0.069	3.169	0.0027
Revenue Maturity(%)	0.520	0.138	3.751	0.0005

Table 9: Regression Analysis between Peak Time of Enterprise Value Growth rate(t) and Peak Time of revenue Growth rate(t)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	7.596	3.524	2.155	0.0362
Peak time of Revenue Growth (t)	0.473	0.152	3.116	0.0031

4.4.4. Prediction of Revenue Maturity Based on Longevity Pharmaceutical Company Resource Profile

Revenue maturity increases by 0.58 units when employee maturity increases by 1 unit at a significant level of 1%. On the other hand, revenue maturity increases by 0.22 units when maturity of Capex increases by 1 unit at a significant level of 5%.

Table 10: Regression Analysis between Revenue Maturity (%) and Employee Maturity (%) & Capex Maturity (%)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	0.006	0.068	0.093	0.9263
Employee maturity (%)	0.581	0.128	4.514	< 0.0001
Capex Maturity (%)	0.219	0.103	2.119	0.0387

The peak time of revenue growth rate increases by 0.62 units when the peak time of employee growth rate increase by 1 unit at a significant level of 1 %. Meanwhile, no linear functional relationship with Capex has been demonstrated.

Table 11: Regression Analysis between Peak Time of Revenue Growth rate(t) and Peak Time of Employee Growth rate & Peak Time of Capex Growth rate(t)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	8.653	2.128	4.065	0.0002
Peak Time of Employee Growth rate(t)	0.619	0.132	4.687	< 0.0001
Peak Time of Capex Growth rate(t)	0.126	0.072	1.751	0.857

That is, based on employee, Capex maturity information and employee growth peak time data, it has been confirmed that it is possible to present a functional model predicting maturity and peak growth time of company's revenue.

On the other hand, the linear relationship with intangible assets has not been demonstrated in terms of maturity and peak time of growth.

Table 12: Regression Analysis between Revenue Maturity (%) and Intangible Asset Maturity (%)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	0.458	0.064	7.163	< 0.0001
Intangible Asset Maturity (%)	-0.036	0.139	-0.264	0.7932

Table 13: Regression Analysis between Peak Time of Revenue Growth rate(t) and Peak Time of Intangible Asset Growth rate(t)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	22.263	5.292	4.206	0.0002
Peak Time of Intangible asset Growth rate(t)	0.043	0.196	0.220	0.8272

4.4.5. Prediction of Enterprise Value Maturity Based on Longevity Pharmaceutical Company Resource Profile

Maturity of the enterprise value increases by 0.41 units when employee maturity increase by 1 unit at a significant level of 5 %.

Table 14: Regression Analysis between Enterprise Value Maturity (%) and Employee Maturity (%)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	0.205	0.101	2.032	0.0477
Employee Maturity (%)	0.407	0.156	2.601	0.0123

The peak time of increase in enterprise value increases by 0.39 units when the peak time of employee growth rate increase by 1 unit at a significant level of 5 %.

Table 15: Regression Analysis between Peak Time of Enterprise Value Growth rate(t) and Peak Time of Employee Growth rate(t)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	11.588	3.130	3.702	0.0006
Peak Time of Employee Growth rate(t)	0.392	0.177	2.215	0.0315

Enterprise value maturity increase 0.60 units when Capex maturity increase by 1 unit at a significant level of 1 %.

Table 16: Regression Analysis Between Enterprise Value Maturity (%) and Capex Maturity (%)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	0.192	0.055	3.479	0.0011
Capex Maturity (%)	0.596	0.112	5.311	< 0.0001

The peak time of increase in enterprise value have not demonstrated a linear functional relationship at the peak time in Capex.

Table 17: Regression Analysis between Peak Time of Enterprise Value Growth rate(t) and Peak Time of Capex Growth rate(t)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	10.982	2.655	4.136	0.0001
Peak Time of Capex Growth rate(t)	0.300	0.102	2.949	0.5000

That is, based on employee, Capex maturity information and growth rate peak time data, it has been confirmed that it is possible to present a model predicting maturity and peak growth time of enterprise value. In contrast, Intangible asset have not demonstrated a linear functional relationship at the peak of their enterprise value, maturity and growth rates.

Table 18: Regression Analysis between Enterprise Value Maturity (%) vs Intangible Asset Maturity (%)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	0.427	0.075	5.669	< 0.0001
Intangible asset Maturity(%)	0.126	0.176	0.715	0.4807

Table 19: Regression Analysis between Peak Time of Enterprise Value Growth rate(t) vs Peak Time of Intangible Asset Growth rate(t)

Variables	Estimated value	Standard Error	t-Statistics	P-value
Cut off	10.586	5.486	1.929	0.0643
Peak Time of Intangible asset Growth rate (t)	0.278	0.198	1.404	0.1717

Table 20: Summary of Statistical Correlation Study on Longevity Pharmaceutical Companies

Correlation Study	Results
Validate correlation between revenue maturity and enterprise value	The cumulative revenue of a company is statistically correlated with enterprise value in terms of maturity (%) and peak time(t) of growth.
Prediction of revenue based on longevity company resource profile	The peak time(t) of growth and maturity(%) in revenue are statistically correlated with the peak time(t) of growth and maturity(%) in employees.
	The maturity(%) in revenue is statistically correlated with maturity(%) in Capex.
	The peak time(t) of growth in revenue is not statistically correlated with the peak time(t) of growth in Capex.
	the maturity(%) and the peak time(t) of growth in revenue are not statistically correlated with the maturity and peak time(t) of growth in Intangible asset.
Prediction of enterprise value based on longevity company resource profile	The maturity(%) and the peak time(t) of growth in enterprise value(%) are statistically correlated with the maturity(%) and the peak time(t) of growth in employees.
	The maturity(%) and the peak time(t) of growth in enterprise value(%) are statistically correlated with the maturity(%) and the peak time(t) of growth in Capex.
	The maturity(%) and the peak time(t) of growth in enterprise value(%) are not statistically correlated with the maturity(%) and the peak time(t) of growth in Intangible asset.

5. Conclusion

The Gompertz model is a highly reliable methodology for predicting dynamic (time series) maturity in a company. In addition, it is possible to analyze information on potential market size(K) and degree of diffusion (b) of companies at the same time. The Gompertz model measured consistency with a correlation coefficient of above 99.5%. The average revenue maturity of 59 Korean pharmaceutical longevity companies was 46.5% and the average remaining life span was more than 50 years. As a result of quantitative life calculation analysis by company, the average life cycle of Korean pharmaceutical longevity companies is 88 years, the average remaining life cycle is 52 years, and the average time of rapid aging (the highest revenue growth rate) is 22 years.

The analysis of revenue maturity and employee input and Capex input maturity patterns of Korean longevity pharmaceutical companies showed that the grand pattern was preceded by employee maturity and growth inflection points, while the Capex had various growth inflection points. This is estimated to appear as a mixture of specialized pharmaceutical businesses such as infectious disease vaccines (followed by investment in tangible assets due to pre-orders) and general pharmaceutical businesses.

As a result of a study on the financial status of a company and the pattern characteristics of resource input, it was found that companies with high profit surplus (high financial stability) inject timely resources similar to the trend of revenue growth.

This study demonstrated that the company's revenue maturity is highly statistically correlated with its enterprise value, confirming the logical validity of the revenue maturity-based corporate life cycle study. It also demonstrated a high statistical correlation between the maturity of a company's resource input and revenue and enterprise value. This confirms that a model of the output function of revenue and enterprise value is possible based on the resource input information of employees and Capex.

First, in predicting future revenue based on the resource profile of longevity pharmaceutical companies, it was possible to quantitatively predict the peak growth time and maturity of revenue growth with the peak growth time and maturity information of employees. On the other hand, Capex was able to quantitatively predict revenue maturity with maturity information, but there was no mutual statistical correlation at the peak time of the growth rate (Table. 20).

This result is helpful for an additional methodology that CEO can determine strategic decisions about whether an expansion (enhancing investment etc.) or management (cost reduction etc.) stance is more appropriate at the current growth timing of a company.

Second, in predicting the future enterprise value based on the resource profile of longevity pharmaceutical companies, it was possible to quantitatively predict the peak growth time and maturity of the growth rate of enterprise value with the peak growth time and maturity information of employees and Capex (Table. 20).

On the other hand, the peak growth time and maturity of intangible assets was not related to maturity and the peak growth time of revenue & enterprise value respectively. This means that intangible assets contribute unclearly to corporate life cycle(revenue) and enterprise value(profit).

This study could be significant in incorporating the Gompertz model, a population growth model, into the study of corporate life, suggesting a quantitative and practical method of diagnosing corporate life cycle. However, the limitation of this study is that it was limited to Korean pharmaceutical sector, and future research will expand the numerical analysis model of this study to foreign countries and companies in various industries to numerically diagnose the life and age of the company and interpret the cause.

References

Adizes. I (1996). *Ten Stages of Corporate Life Cycles,* Inc, *18*(14), page 95.

Aldrich. H. E. (1979). *Organizations and environments,* Englewood Cliffs, NJ: Prentice-Hall.

Aldrich H. E. (1999). *Organizations evolving,* Thousand Oaks, CA: Sage.

Anthony, J. H., & Ramesh, K. (1992). Association between accounting performance measures and stock prices: A test of the life cycle hypothesis, *Journal of Accounting and economics*, *15*(2-3), 203-227.

Bens, D. A., Nagar, V., & Wong, M. F. (2002). Real investment implications of employee stock option exercises, *Journal of Accounting Research, 40*(2), 359-393.

Bellone, F., Musso, P., Nesta, L., & Quéré, M. (2008). Market selection along the firm life cycle, *Industrial and Corporate Change, 17*(4), 753-777.

Cefis, E., & Marsili, O. (2019). Good times, bad times: innovation and survival over the business cycle. *Industrial and Corporate Change, 28*(3), 565-587.

Cziglerné Erb, E. (2020). The Re-emergence of the Residual Income Model in the Valuation of Firms and Investment Projects. *PÉNZÜGYI SZEMLE/PUBLIC FINANCE QUARTERLY, 65*(3), 430-442.

DeAngelo, H., DeAngelo, L., & Stulz, R. M. (2006). Dividend policy and the earned/contributed capital mix: a test of the life-cycle theory, *Journal of Financial economics, 81*(2), 227-254.

Dickinson, V. (2011). Cash flow patterns as a proxy for firm life cycle, *The Accounting Review, 86*(6), 1969-1994.

Domingues, J. S. (2012). Gompertz model: Resolution and analysis for tumors, *Journal of Mathematical Modelling and Application, 1*(7), 70-77.

Hirshleifer, J. (1978). Competition, cooperation, and conflict in economics and biology, *The American Economic Review, 68*(2), 238-243

Hannan M. T. and Freeman. J. (1989), *Organizational ecology. Cambridge,* MA: Harvard University Press.

Jha, A., & Saha D. (2018). Diffusion and forecast of mobile service generations in Germany, UK, France, and Italy comparative analysis based in Bass, Gompertz and simple losistic growth models, *Proceedings of Twenty-Sixth European Conference on Information Systems (ECIS2018)*. Portsmouth, UK.

Jha, A., & Saha, D. (2020). Forecasting and analysing the characteristics of 3G and 4G mobile broadband diffusion in India: A comparative evaluation of Bass, Norton-Bass, Gompertz, and logistic growth models, *Technological Forecasting and Social Change, 152*, 119885 https://doi.org/10.1016/j.techfore.2019.119885

Jiang, X., & Lee, B. S. (2005). An empirical test of the accounting-based residual income model and the traditional dividend discount model, *The Journal of Business, 78*(4), 1465-1504.

Lippitt G. L. & Shumdit W. H. (1967). *Crises in a developing organization: Organization confrontations test managerical fitness in the same way that individual crises test human fitness,* George Washington University.

Manson. S. M. (2001). Simplifying complexity: a review of complexity theory. *Geoforum, 32*(3), 405-414.

Menzel, M. P., & Fornahl, D. (2010). Cluster life cycles—dimensions and rationales of cluster evolution, *Industrial and corporate change, 19*(1), 205-238.

Olukayode, A. S. (2019). A Numerical Analysis of Basis Function on Population Growth Using Gompertz Approach, *American Journal of Mathematical and Computer Modelling, 4*(1), 21-26.

Ohlson, J. A. (1995). Earnings, book values, and dividends in equity valuation, *Contemporary accounting research, 11*(2), 661-687.

Peltoniemi, M. (2005). *Company Ecosystem: A Conceptual Model of an Organization Population from the Perspectives of Complexity and Evolution,* e-BRC Research Reports, 18.Tampere: Finland.

Perek, A. A., & Perek, S. (2012). Residual income versus discounted cash flow valuation models: An empirical study, *Accounting & Taxation, 4*(2), 57-64.

Rapport, D. J., & Turner, J. E. (1977). Economic models in ecology, *Science,* 195(4276), 367-373.

Tsai, B. H. (2013). Predicting the diffusion of LCD TVs by incorporating price in the extended Gompertz model, *Technological Forecasting and Social Change, 80*(1), 106-131.

Tatro, D. (2018). *The Mathematics of Cancer: Fitting the Gompertz Equation to Tumor Growth.*

Zardin, A. M. D. S. O., de Oliveira, C. A. L., de Oliveira, S. N., Yoshida, G. M., de Albuquerque, D. T., de Campos, C. M., & Ribeiro, R. P. (2019). Growth curves by Gompertz nonlinear regression model for male and female Nile tilapias from different genetic groups. *Aquaculture, 511*, 734243.