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A Study on the New Risk-adjusted Net Present Value (rNPV) Technology Valuation: About Risk-Adjustment

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***Abstract*-- As the importance of technology has recently increased, technology valuation has also become very important. In particular, the pharmaceutical and bio industries calculate the technology value using the rNPV technology valuation method to reflect the characteristics and risk factors of drug development. However, in the risk-adjustment of rNPV, there was a section where the value increased rather than decreased even though the risk was reflected. Therefore, a theoretical analysis of risk and risk-adjustment and an rNPV model for problem solving were presented, and an empirical analysis was conducted according to the increase in risk. As a result of the study, the new rNPV model confirmed the practicality and resolution of the existing problems in which the value increases after risk-adjustment. This study improved the problems of the rNPV model, which did not properly adjust risk, and presented a new model. Therefore, it is expected that the new rNPV model presented in this study will be used as a tool to perform technology valuation more accurately than the existing model in the pharmaceutical and bio industries.**

***Keywords*-- rNPV, technology valuation, risk-adjustment, risk, probability of success**

INTRODUCTION

The pharmaceutical and bio industry is a high risk industry that requires a long development period of about 15 years and a development cost of 2-3 trillion KRW [1].However, successful drug development in this industry can lead to high-value products that dominate the market until the patent expires [1][2].Drug development in the pharmaceutical and bio industry has several characteristics different from other industries. Drug development requires a drug approval process after candidates have passed preclinical and clinical trials [3].In addition, each country needs procedures to approve clinical trials and drug launches through relevant organizations such as the US Food and Drug Administration (FDA) and the European Medicines Agency (EMA) [4].

Therefore, in the development of drugs, there is a risk of failure and costs incurred without sales in case of failure [2].

Recently, the share of intangible assets in companies is continuously increasing, and businesses based on technology assets are developing [5][6].In particular, the importance of the pharmaceutical and bio industries has been further emphasized due to the recent COVID-19 pandemic [7]. The global pharmaceutical market in the pharmaceuticalbio sector is expected to show an average annual growth rate of 5.3% [8]. However, indrug development, R&D costs and time required for drug development tend to increase as the initial investment cost for discovering candidate substances increases and human safety regulations are strengthened [9].Therefore, in order to relieve the burden of a lot of time and development costs, pharmaceutical companies are attempting technology transfer to Big Pharma for drugs that have undergone preclinical, phase 1, and phase 2 clinical trials [10][11].A technology valuation process is essential for technology transfer [8]. In addition, in the pharmaceutical and bio industry, where there is no alternative in case of failure, technology valuation, which predicts economic benefits for technologies owned by companies or technologies under development, is more important [12].Technology valuation in the pharmaceutical and bio industries uses the risk-adjusted net present value(rNPV) method, which reflects uncertain risk factors such as the success rate of new drugs and the possibility of competitive new releases at each development stage.

Technology valuation using the rNPV method considers the possibility of success in each clinical trial stage and development period in addition to variables such as the economic lifespan of technology, cash flow (CF) estimation, discount rate, and technology contribution [4]. Technology valuation via the rNPV method is also used in many studies and practical work[14]-[16].

The rNPV method performs risk-adjustment (RA) by reflecting the risk-adjustment index (RAI) called the probability of success (POS) in the present value of cash flow (PV of CF) [14].Risk is defined as the uncertainty about the possibility of a particular situation occurring [17], and generally means loss or possibility of loss of value [18].This possibility is the probability of failure (POF) in a clinical trial [2]. From an investment point of view, risky assets require greater risk than relatively safe ones. Therefore, a higher expected rate of return is expected, and the reflection of the risk according to that expectation leads to a high discount rate, which lowers the initial value [2].Therefore, if there is a POF, the value of CF is risk-adjusted in a decreasing direction [2][19]. The use of the existing rNPV model was also risk-adjusted in the direction of decreasing values based on this point [20]-[22].

This study focuses on the RA of the rNPV method and aims to appropriately reflect the risk in the technology valuation of the pharmaceutical and bioindustry. Therefore, CF patterns for 'present value' and 'technology value determination', in which the amount decreases like RA and RA of 'rNPV calculation' using the rNPV model, were analysed.Through this, in the rNPV model, the positive CF was appropriately reflected in the risk due to the decrease in value due to RA. However, it was found that negative CF does not properly reflect risk and increases in value when RA.Therefore, we proposed a new risk-adjusted net present value (nrNPV) model and identified a solution to the problem that RA for negative CF increases time value.In addition, the practicality of the nrNPV model was confirmed by an empirical analysis of the RA of CF according to the decrease in the POS for the nrNPV model. Therefore, the nrNPV model is expected to enable more accurate technology valuation in the pharmaceutical and bio industries.

LITERATURE REVIEW

A. Technology Valuation

The role of technology evaluation to evaluate the economic value of technology is important in the process of technology commercialization, and its utilization is expected to further increase in the future [23][24]. ‘Technology valuation’ is the evaluation of the economic value generated by technology through a business based on historical information such as business revenues and costs, in accordance with generally accepted valuation principles and methodologies [25]-[27]. In various valuation standards, the market value derived through the normal trading of the market is selected as the value standard, so the market value is recognized as the basis of value [12].

According to the use and purpose of technology valuation, there is a market approach, a benefit approach, and a cost approach [28]. The revenue approach is a value calculation method based on the technology factor method, which derives value by discounting future economic benefits arising from the economic life of a target technology to its present value (PV) [14]. The technology factor method is a method for calculating the technology contribution by reflecting the technology factor, which is the proportion of technology assets that contribute to the economic benefits generated during commercialization along with the characteristics of the industry and individual technology [28]. The market approach is a method of estimating relative value through comparison and analysis of how much similar technology has been traded in a related market [14]. The cost approach is a method of estimating the value of a technology by estimating the cost required to develop or purchase a technology with the same economic benefit according to the principle of economic substitution [14]. The net present value (NPV) method is a valuation method based on the discounted cash flow (DCF) method and is one of the income approach methods. It is an economic valuation method that subtracts the PV of future cash outflows from the PV of future cash inflows [12].

Drug development is an industry with an overall success rate of about 0.02%, but it is an industry that reaps high profits when new drug development is successful [10]. Drug development requires a preclinical, Investigational New Drug (IND) approval process for the efficacy and safety of discovered drug candidates, stage 1st to 3rd clinical trials and new drug application (NDA) approval [2]. IND and NDA approvals require approval from relevant authorities such as the US Food and Drug Administration (FDA) and the European Medicines Agency (EMA) [3].

In drug development, the risk is much higher than in other industries because it is impossible to compensate for the failure of a major project, so technology evaluation is more important for decision-making before technology commercialization [2][8].

Jeffrey J. S. et al. (2001) proposed the rNPV method shown in [Figure 1] because there are several risk factors in technology valuation for the pharmaceutical and bio industries, which could result in an overestimation of the technology value in the case of the NPV method. Since the NPV method does not reflect the risks characteristic of the pharmaceutical and bio industry, the rNPV method can reflect the characteristics of the pharmaceutical and bio industry [12] [19]. The rNPV method is a commonly used valuation method in the life sciences industry [13].

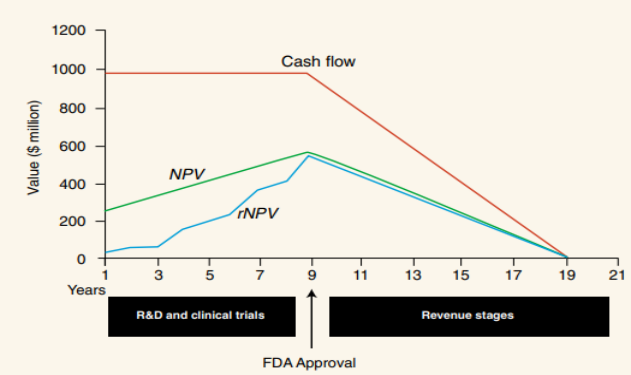

Figure 1. The value of biotechnology [19]

Technology valuation using the rNPV method additionally considers the economic life of the technology, CF estimation, discount rate, and technology factor as well as the success rate and development period in clinical trials that vary depending on the type of drug [4]. rNPV converts future CF into present CF through a discount rate, reflects the success rate of new drugs step by step as a RAI, calculates the total business value by summing the CF, and determines the technology value using the technology factor. [14]. The rNPV model is based on the DCF method, which assumes that the discount rate and CF growth rate are constant each year and that decision making always proceeds to the next step [29].

'Present value' means that the future CF of a target technology is converted into PV by applying a discount rate that considers various risks inherent in the technology commercialization process [14]. 'rNPV calculation' is calculated by multiplying the PV of annual CF by the RAI, which is the POS [2][4]. The POS of a drug is calculated by multiplying the probability of entering the development stage by the cumulative probability of the drug before that stage [4][19]. 'Technology value determination' determines the technology value by multiplying the technology factor out of the total commercialization value obtained through rNPV calculation [14]. Technology factor is defined as the contribution ratio of the target technology to the total business value using the industrial technology factors, technology share, and strengths of individual technologies according to the technology factor method [28].

Technology evaluation using the rNPV method is largely divided into a general method and a royalty-based method [14]. Therefore, in this study, the technical value of the general rNPV method is premised on the description. The technology evaluation process according to the general rNPV method is shown in [Figure 2].

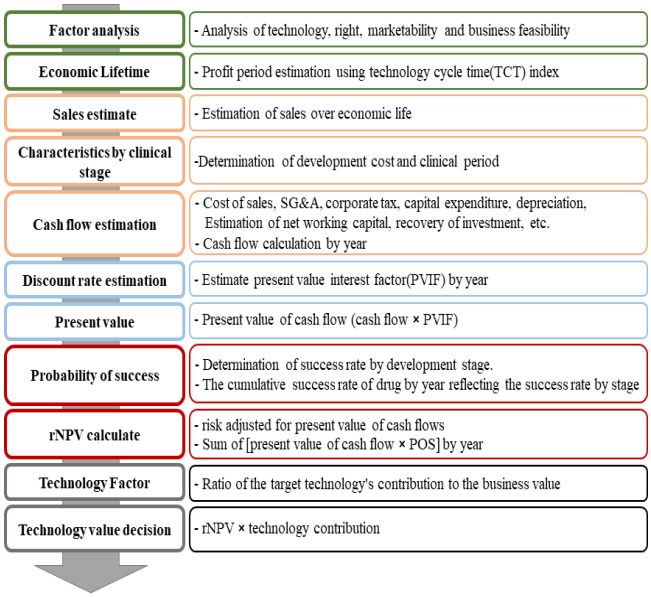

Figure 2. Technology valuation process using rNPV [14]

The determination of technology value using the rNPV model is represented by following Equation (1) [14].

$$Technology\ value \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

$$= \left[\sum_{t=1}^{n} \frac{CF_t \times POS_t}{(1+r)^t}\right] \times T.F$$

- t: t year
- n: cash flow estimation period
- CF_t: cash flow in t year
- r: dicount rate
- POS_t: probability of success(cumulative success rate)
- T. F: technology factor

B. Technology ValuationofDrug Development

Risk is defined as the uncertainty about the chance of a positive or negative situation affecting a specific purpose or goal [17].Risk generally also means the possibility of damage or loss of value [18].Economically, risk is divided into 'risk', in which it is possible to know how accurate the prediction is based on quantitative knowledge such as statistics, and 'uncertainty', in which it is impossible to predict to what extent the prediction will be realized [30].Therefore, in this study, the POS of a drug in the rNPV method is based on statistical grounds through existing cases, so the risk is described in the sense of 'risk'. Risk indrug development is the failure of a drug candidate substance in a clinical trial, resulting in financial loss, which means the POF [2][4].

Highrisk CF are worth less than less-risky CF [31].From an investment point of view, risky assets are expected to have high expected rates of return due to their high risk compared to relatively safe assets, and this is reflected in a high discount rate, resulting in low value [2].In other words, when the risk is reflected, the value moves in a decreasing direction.

C. Risk-adjustment of rNPV

Risk is defined as uncertainty about the likelihood of a positive or negative circumstance affecting a particular purpose or objective [17]. Risk also generally refers to the possibility of damage or loss of value [18]. Economically, risk is divided into risk, a state in which one can know almost exactly how accurate an expectation is based on quantitative knowledge such as statistics, and uncertainty, a state in which an expectation cannot be predicted. [30]. Therefore, in this study, the POS by the rNPV method was described in the sense of 'risk' based on statistical grounds through existing cases.

Drug development risk refers to the probability that a drug will fail due to financial loss when a candidate substance fails in a clinical trial [2][4]. Due to the nature of the pharmaceutical and bio industry, where there is no alternative in the event of a preceding project failure, the probability consists only of the POS and POF [14]. That is, the POS is the value obtained by subtracting the POF from the 100% probability.

Highrisk CF have a smaller value than low-risk CF [31]. From an investment point of view, risky assets are expected to have a high expected rate of return due to their high risk compared to relatively safe assets, which leads to a high discount rate, leading to underestimation of their value [2]. If there is a risk as a company, it must additionally bear the scale of the risk [12]. That is, when risk is reflected, the value moves in a decreasing direction.

RA is 'compensation required to bear the uncertainty of the amount and timing of CF due to non-financial risk and is an additional liability to compensate for the uncertainty of estimation in the general model for measuring insurance liabilities [32]. The RA in the rNPV method reflects the risk using a RAI called the POS [14]. In other words, the RA of drug development fluctuates in a decreasing direction due to additional debt to compensate for the uncertainty in the POF.

rNPV MODEL ANALYSIS

A. rNPV technology valuation analysis

The target technology is an incrementally modified drug that improves the dosage form of an already approved treatment, and is currently in pre-clinical trials working in progress (WIP), and the commercialization preparation period is 5 years (pre-clinical (PC) in the first year, phase 1(P1) clinical trial in the second year, phase 2 (P2) clinical trial in the third year, phase 3 (P3) clinical trial in the fourth year, NDA approval in the fifth year, market launch in the sixth year) was assumed [14].

Evaluation assumptions and conditions are shown in [Table 1].

TABLE 1
TECHNOLOGY VALUATION ASSUMPTIONS AND CONDITIONS [14]

Business model	Supply of injections through self-commercialization
Business entity	Domestic unlisted medium-sized enterprises
Target technology	IMD that changes the dosage form from an existing oral drug to an injection
Product and target market	Degenerative disease treatment (dementia treatment)
Sectors	Manufacturing of finished pharmaceuticals (C21210)
Development stage	Preclinical trial in progress
Target market scope	domestic market (Korean market)
Commercialization preparation period	5 years

Based on the assumptions and conditions, the estimated period of CF (13 years), CF (cost of sales, SG&A, corporate tax, depreciation, capital expenditure, change in working capital, return of investment) are calculated, and the discount rate (Weighted Average Cost of Capital, WACC) 9.41% was reflected to obtain the PV of the CF [14].

The POS in each stage of clinical trials and the cumulative probability are shown in [Table 2]. The target technology is an improved new drug with an improved formulation for an already licensed treatment, and the success rate for each clinical stage in the field of non-new molecular entities (non-NME) was referred to [33]. The cumulative POS is calculated by multiplying the probability of entering the clinical stage by the POS in previous stages [4][19].

TABLE 2
PROBABILITY OF SUCCESS BY CLINICAL STAGE [33]

Division	PC	P1	P2	P3	NDA	Approval
Current Status	WIP					
POS	100%	70.1%	48.3%	73.9%		
Cumulative probability	100%	100% (100×100)	70.1% (100×70.1)	33.9% (70.1×48.3)	25.0% (33.9×73.9)	22.6% (25.0×90.4)
Period	PC	P1	P2	P3	Approval	Market launch

The technology valuation of the rNPV model is shown in [Table 3]. The CF before RA are equal to the PV of CF, and the CF after RA are equal to the risk-adjusted CF.

1st to 6th years had negative CF, and 7th to 13th years had positive CF. In 1st to 2nd years, the value did not change according to risk adjustment. In 3rd to 6th years, the value increased, and in 7th to 13th years, the value decreased.

To determine the technology value, a technology contribution of 41.79% (industrial technology factor 85.28%, technology share 70%, technology strength 70%) was calculated and multiplied by rNPV, and the final technology value of 1,335 million KRW was determined [14].

B. Analysis of the rNPV procedure

In the procedure using the rNPV method, the difference between risk adjustment of 'rNPV calculation' and CF of 'present value' and 'determination of technology value', in which the amount decreases like risk adjustment, was analyzed.In each analysis, we placed particular emphasis on analysing the impact of value fluctuations and negativity.

'Present value' is a kind of 'conversion' concept that converts future CF into current values, and there is no change in each other's values [2][4].For example, the future value (FV) of 100 is discounted by 30% through a reduction rate called the present value interest factor (PVIF) of 0.7 and converted to a PV of 70 [Figure 3].In other words, the FV of 100 and the PV of 70 have the same market value.

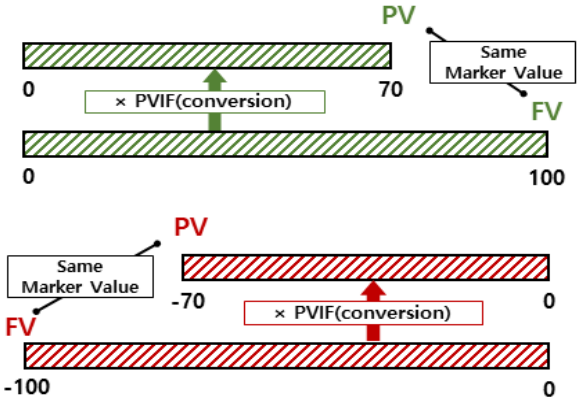

Figure 3. Present value of cash flow

'Technology value decision' are the concept of 'ratio' that technology occupies the entire business value [28].Therefore, even if the total business value is negative, it is a ratio of technology, so there is no separate impact on negative numbers. For example, it is shown in [Figure 4] as a method of determining Technology Value of -30 by reflecting a 30% technology factor in the entire business value of -100.

TABLE 3
TECHNOLOGY VALUATION OF rNPV MODEL [14]

(Unit: million KRW)

Division	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
PV of CF	-2,324	-1,547	-1,622	-3,404	-1,934	-362	2,257
POS (Cumulative probability)	100%	100%	70.1%	33.9%	25.0%	22.6%	22.6%
Risk-adjusted CF	-2,324 (-2,324×100%)	-1,547 (-1,547×100%)	-1,137 (-1,622×70.1%)	-1,153 (-3,404×33.9%)	-484 (-1,934×25.0%)	-82 (-362×22.6%)	511 (2,257×22.6%)
Division	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	
PV of CF	5,371	6,212	8,202	7,432	6,236	8,149	
POS (Cumulative probability)	22.6%	22.6%	22.6%	22.6%	22.6%	22.6%	
Risk-adjusted CF	1,215 (5,371×22.6%)	1,405 (6,212×22.6%)	1,855 (8,202×22.6%)	1,681 (7,432×22.6%)	1,411 (6,236×22.6%)	1,843 (8,149×22.6%)	
Sum of risk-adjusted cash flows (rNPV)				3,194			
Technology Factor				41.79% (85.28%×70%×70%)			
Technology Value				1,335			

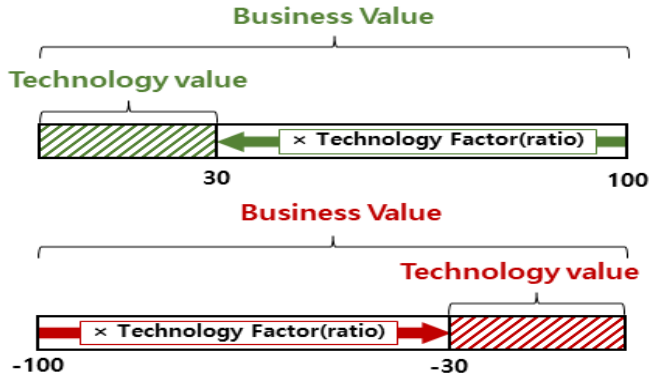

Figure 4.Technology value decision

'rNPV calculation' process is a concept of 'adjustment' that is made by reflecting a RAI in the PV of CF [14].Since the investor assumes the risk, risk adjustment reflects this risk as a decrease in value due to additional liabilities [2][34].For example, RA (a) and risk-adjusted CF (b) according to the rNPV model is as shown in [Figure 5] when the POS of 10% is applied to the PV of CF of 100 and -100.

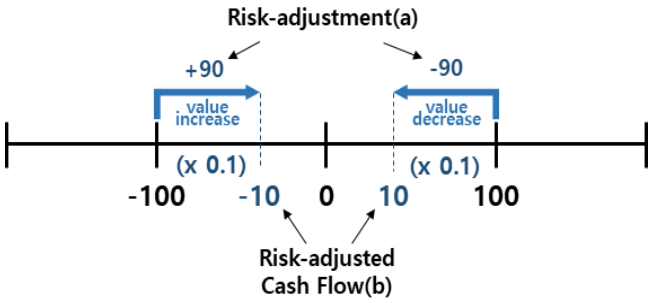

Figure 5. Risk-adjustment of rNPV model

In the rNPV model, the probability consists of only the POS and POF because there is no suboptimal solution [2]. Therefore, RA (a) and risk-adjusted CF (b) are as in Equation (2).

$$Risk\text{-}adjustment\ (a) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

$$= CF \cdot PS - CF$$
$$= CF(PS - 1)$$
$$= -CF \cdot PF$$
$$Risk\text{-}adjusted\ Cash\ Flow\ (b)$$
$$= CF - CF \cdot PF$$
$$= CF(1 - PF)$$
$$= \mathrm{CF(PS)}$$

· PF: probability of failure (risk)
· PS: probability of success (1 − risk)
· CF: present value of cash flow

As a result, in the case of 100, the value decreased by -90, but in the case of -100, the value increased by +90.This shows that the RA for positive and negative CF is different, and the RA for rNPV is not properly performed for negative CF.

This phenomenon has also been shown in a number of previous studies [2][10][14][19].In addition, when the cost was viewed from the perspective of loss such as negative CF, the value increased as the cost decreased after RA when calculating the expected cost according to clinical trials [35].

rNPV Model Analysis

A. *nrNPV model*

In this study, the nrNPV model is presented to solve the problem of the rNPV model in which risks are not properly reflected because positive and negative CF are risk-adjusted differently. In addition, an empirical analysis was conducted on the RA of the nrNPV model according to the decrease in the POS.

In order to properly reflect the risk of the rNPV model, risk adjustment for negative CF should be performed as shown in [Figure 6]. In other words, when a 10% POS is reflected in a CF of -100, the value should be reduced by -90 to show a risk-adjusted CF of -190.

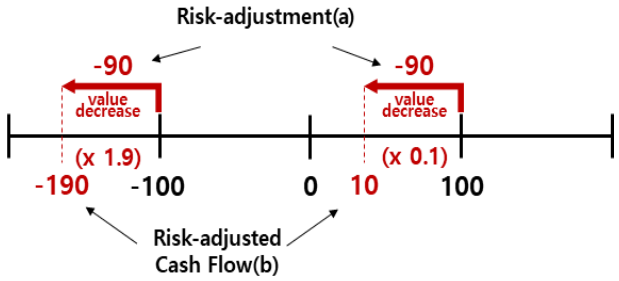

Figure 6. Risk-adjustment of nrNPV model

Therefore, in order to ensure that RA is the same for both positive and negative CF, this study proposes Equation (3) for RA (a) and risk-adjusted CF (b) for negative CF.

$$(IF.\ CF < 0) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (3)$$

$$Risk\text{-}adjustment(a) = CF - CF \cdot PS$$
$$= CF(1 - PS)$$
$$= CF \cdot PF$$
$$Risk\text{-}adjustedCashFlow(b)$$
$$= CF + CF \cdot PF$$
$$= CF(1 + PF)$$
$$= CF(2 - PS)$$

· PF: probability of failure (risk)
· PS: probability of success (1 − risk)
· CF: present value of cash flow

It is also considered that the profit and loss are more than simply greater than or less than 0, and the present value (PV) of cash flow is divided into cases of positive PV indicating profit and negative PV indicating loss to reflect risks differently. In this study, the determination of technology value using the nrNPV model is proposed and shown in Equation (4).

TABLE 5
SUM OF RISK-ADJUSTED CF IN 3rd TO 6th YEARS

(Unit: million KRW)

Division	3rd to 6th years
PV of CF	-7,322
rNPV model	-2,856
nrNPV model	-11,788

$$Technology\ value \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (4)$$

$$= \left[\sum_{t=1}^{n} \frac{CF_t \times RAI_t}{(1+r)^t}\right] \times T.F$$

$$(IF.\ CF_t \geq 0\ or\ profit)$$
$$RAI = POS_t$$

$$(IF.\ CF_t < 0\ orloss)$$
$$RAI = (2 - POS_t) = (1 + POF_t)$$

· t: t year
· n: cash flow estimation period
· CF_t: cash flow in t year
· r: dicount rate
· RAI: risk-adjustment index
· POS_t: probability of success (cumulative success rate)
· POF_t: probability of failure (cumulative success rate)
· T. F: technology factor

The nrNPV model is the same as before when CF are profit, but the RA is different when CF are loss. In addition, when calculating the expected cost of a clinical trial, the cost should be regarded as a loss and RA should be made by adding the POF to 100%.

The RA for the CF of the nrNPV model proposed in this study is shown in [Table 4].All conditions except for the negative CF variable are the same as for the rNPV model.The sum of risk-adjusted CF (= rNPV) calculated based on the rNPV method was calculated at 3,194 millionKRW, and the sum of risk-adjusted CF calculated based on the nrNPV method was calculated at -5,738 million KRW.Since the two rNPV models have a difference only when the CF is negative in RA, we focused on 1st to 6th yearswhen negative CF occurred.There was no risk in the 1st to 2nd years when the new drug success rate was 100%, so there was no difference according to the risk adjustment according to the two rNPV models, but a large difference was seen in the 3rd to 6th years. As an example of the 3rd year CF, the rNPV method has a 70.1% POS, so the risk-adjusted CF is -1,137 (-1,622 × 70.1%) million KRW.

The risk-adjusted CF differences for CF in years 3rd to 6th, which show the main differences in the two rNPV models show in [Table 5]. The sum of risk-adjusted CF in 3rd to 6th years was -2,856 million KRW for the rNPV model and -11,788 million KRW for the nrNPV model, and the two models showed a difference of 8,932 million KRW.As a result, the nrNPV model solved the problem of the rNPV model by appropriately reflecting the decrease in value due to RA when the PVof CF is negative.

TABLE 4
TECHNOLOGY VALUATION OF nrNPV MODEL

(Unit: million KRW)

Division	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
PV of CF	-2,324	-1,547	-1,622	-3,404	-1,934	-362	2,257
POS (Cumulative probability)	100%	100%	70.1%	33.9%	25.0%	22.6%	22.6%
Risk-adjusted CF	-2,324 (-2,324×100%)	-1,547 (-1,547×100%)	-2,107 (-1,622×129.9%)	-5,654 (-3,404×166.1%)	-3,385 (-1,934×175.0%)	-642 (-362×177.4%)	511 (2,257×22.6%)
Division	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	
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POS (Cumulative probability)	22.6%	22.6%	22.6%	22.6%	22.6%	22.6%	
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Sum of risk-adjusted cash flows (rNPV)				3,194			
Technology Factor				41.79% (85.28%×70%×70%)			
Technology Value				1,335			

B. nrNPV model analysis according to risk increase

In the nrNPV model, when the risk increases, the difference in risk adjustment was compared with the rNPV model for empirical analysis.For the empirical analysis, CF from 3rd to 6th years, which show the main difference, were used. As a model comparison according to the risk increase, 100%, 95%, 90%, 85%, ⋯, 0%, the RAI, which continues to decrease to 0%, was reflected as shown in [Table 6].

The risk-adjusted CF by year is shown for the CF of 3rd to 6th years, and the size of RA compared to the CF converted to PV is analyzed.The sum of the 3rd to 6th year CF is unchanged for both models because there is no risk when the POS is 100%. When the POS is 95%, the nrNPV model shows a RA of -366 million KRW, with the sum of risk-adjusted CF being -7,688 million KRW. However, the rNPV model shows a RA of +366 million KRW, with the sum of risk-adjusted CFbeing -6,956 million KRW.In the range of 5 to 90% POS, the size of RA increased or decreased regularly by 366 million KRW.At 0% POS, the nrNPV model showed a risk adjustment of -7,322 million KRW, with the sum of risk-adjusted CF being -14,644 million KRW. However, the rNPV model showed a risk adjustment of +7,322 million KRW, with the sum of risk-adjusted CF being zero. As a result, showing a maximum difference of 14,644 million KRW in the sum of risk-adjusted CF according to the two models.The size of RA can vary depending on the amount, but in the two models, the RA direction in which the difference in value widens as the POS decreases is shown in [Figure 7].

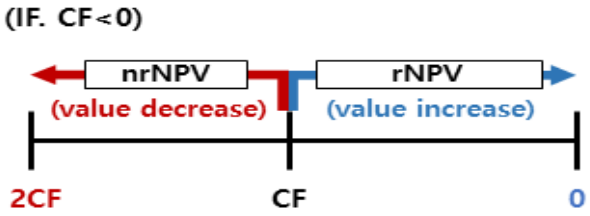

Figure 7. Risk adjustment direction

In the case of the nrNPV method, as the risk increased, the risk-adjusted CF got closer and closer to 2 times the PV of CF. In the rNPV method, the risk-adjusted CF got closer and closer to zero. In other words, the lower the POS, the wider the difference between the two models.When the POS is 100%, there is no difference between the values according to the two models.When the POS is 0%, the value according to the two models shows a difference of up to two times the PV of CF.As a result, the practicality of the nrNPV model was confirmed mainly in drug development with a low success rate.

CONCLUSION

This study focused on the RA of the rNPV method and aimed to appropriately reflect the risk.Regarding the technology valuation process using the rNPV method, aspects according to CF were analyzed in 'rNPV calculation', 'present value', and 'technology value determination' of the

TABLE 6
CHANGE IN RISK-ADJUSTED CF AS RISK INCREASE

(Unit: million KRW)

nrNPV						POS	rNPV					
3rd	4th	5th	6th	SUM	RA		3rd	4th	5th	6th	SUM	RA
-1,622	-3,404	-1,934	-362	-7,322	0	**100%**	-1,622	-3,404	-1,934	-362	-7,322	0
-1,703	-3,574	-2,031	-380	-7,688	-366	**95%**	-1,541	-3,234	-1,837	-344	-6,956	+366
-1,784	-3,744	-2,127	-398	-8,054	-732	**90%**	-1,460	-3,064	-1,741	-326	-6,590	+732
-1,865	-3,915	-2,224	-416	-8,420	-1,098	**85%**	-1,379	-2,893	-1,644	-308	-6,224	+1,098
-1,946	-4,085	-2,321	-434	-8,786	-1,464	**80%**	-1,298	-2,723	-1,547	-290	-5,858	+1,464
-2,028	-4,255	-2,418	-453	-9,153	-1,831	**75%**	-1,217	-2,553	-1,451	-272	-5,492	+1,831
-2,109	-4,425	-2,514	-471	-9,519	-2,197	**70%**	-1,135	-2,383	-1,354	-253	-5,125	+2,197
-2,190	-4,595	-2,611	-489	-9,885	-2,563	**65%**	-1,054	-2,213	-1,257	-235	-4,759	+2,563
-2,271	-4,766	-2,708	-507	-10,251	-2,929	**60%**	-973	-2,042	-1,160	-217	-4,393	+2,929
-2,352	-4,936	-2,804	-525	-10,617	-3,295	**55%**	-892	-1,872	-1,064	-199	-4,027	+3,295
-2,433	-5,106	-2,901	-543	-10,983	-3,661	**50%**	-811	-1,702	-967	-181	-3,661	+3,661
-2,514	-5,276	-2,998	-561	-11,349	-4,027	**45%**	-730	-1,532	-870	-163	-3,295	+4,027
-2,595	-5,446	-3,094	-579	-11,715	-4,393	**40%**	-649	-1,362	-774	-145	-2,929	+4,393
-2,676	-5,617	-3,191	-597	-12,081	-4,759	**35%**	-568	-1,191	-677	-127	-2,563	+4,759
-2,757	-5,787	-3,288	-615	-12,447	-5,125	**30%**	-487	-1,021	-580	-109	-2,197	+5,125
-2,839	-5,957	-3,385	-634	-12,814	-5,492	**25%**	-406	-851	-484	-91	-1,831	+5,492
-2,920	-6,127	-3,481	-652	-13,180	-5,858	**20%**	-324	-681	-387	-72	-1,464	+5,858
-3,001	-6,297	-3,578	-670	-13,546	-6,224	**15%**	-243	-511	-290	-54	-1,098	+6,224
-3,082	-6,468	-3,675	-688	-13,912	-6,590	**10%**	-162	-340	-193	-36	-732	+6,590
-3,163	-6,638	-3,771	-706	-14,278	-6,956	**5%**	-81	-170	-97	-18	-366	+6,956
-3,244	-6,808	-3,868	-724	-14,644	-7,322	**0%**	0	0	0	0	0	+7,322

rNPV model, and the nrNPV model was presented.

In addition, for the nrNPV model, an empirical analysis was conducted on CF after RA according to the decrease in the POS. The conclusions of this study are as follows.

First, 'rNPV calculation' is the 'adjustment' of the value by the RAI of the POS according to the risk.Risky assets lead to a higher expected rate of return because they have to take risks than when they are safe from an investment point of view. This leads to a lower initial value due to RA using a higher discount rate.However, in the rNPV model, an error was found in which RA occurs in the direction of increasing value in negative CF.Through this, it was confirmed that the RA of the rNPV model was not performed properly when the CF was negative.

Second, the nrNPV model was presented to solve the problem of the rNPV model in which RA was made in the direction of increasing value in negative CF. In the negative CF, the nrNPV model did not show a difference from the rNPV model because the risk did not exist when the POS was 100%. However, the value decreased when the POS was not 100%, showing a major difference from the rNPV model. Through this, the nrNPV model confirmed the problem solving of the rNPV model.

Third, the nrNPV model empirical analysis of the change in CF due to a decrease in POS. In particular, we analyzed the CF of the 3rd-6th years, which showed the main difference from the rNPV model. When the POS was 100%, there was no difference in value for the two models. However, nrNPV has increased RA when the POS decreases in the CF of negative, and it was the maximum when the chance of success is 0%.Furthermore, while the RA direction of the rNPV model approached zero, the nrNPV model showed a difference that approached twice the PV of CF. Based on these results, it was confirmed that the nrNPV model, which can more accurately reflect the risk in drug development with high risk due to low POS, is more practical.

Additionally, the technology value obtained through technology valuation case analysis was estimated to be 3,194 million KRW for the rNPV model, indicating business value. However, for the nrNPV method, the estimated value was -2,398 million KRW, indicating no business value. Thus, in cases where business value existed in previously technology valuation cases, applying nrNPV could result in a change to no business value. Furthermore, when estimating expected costs based on clinical trials, a RA by adding POF as a negative cost may result in fluctuations in the existing technology valuation results. Therefore, it is expected that the nrNPV model presented in this study can establish a foundation for more accurate technology valuation in the pharmaceutical and biotech industries.

A limitation of this study is that the cases and contents of technology valuation are often kept confidential because they can be directly linked to a company's information. Therefore, there was a limitation in using various technology valuation cases. Thus, for future research in technology valuation, analysis of various cases will be necessary.

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