Asian Journal of Innovation and Policy (2017) 6.2:206-224
DOI: http//dx.doi.org/10.7545/ajip.2017.6.2.206

Measurement of Public Research Outcomes: A Technology Valuation Method

Jung-Min Park*, Seong-Il Lim, Sung-Soo Seol *****

Abstract This article proposes a logic model for assessing the performance of the outcome of public research as a technology valuation method. It consists of two parts and eight steps. The first part is a scoring system and the second part is a validation process of the performance index derived from scoring by valuation method. The scoring in the first part generally requires a focus group method to find out the value drivers and make an evaluation table. The reason why we call it the technology valuation method is that the first part is derived from the simple evaluation of technology value using checklists for value drive. The second part is the regular technology valuation process. The model is designed for the measurement of unquantifiable outcome. Is knowledge or scientific outcome comparable to the measured outcome? If possible, how big is the unquantifiable outcome? This model is based on financial valuation techniques with clear or acceptable market data. Therefore, it cannot work solely for unquantifiable outcomes without comparable measurable outcomes, unlike economic valuation.

Keywords Performance measurement, technology valuation method, scoring system of assessment, performance index, value driver.

I. Introduction

Everywhere R&D is conducted, R&D performance is a challenging issue to be addressed. In particular for R&D targeting, assessment is crucial to all aspects of R&D management for enhancing efficiency, effectiveness and relevance. However, R&D assessment is not easy because of several issues: the time issue such as in-process, output, outcome and impact; the comparison issue between different types of results related to scientific, technological, economic, social and cultural dimensions; the stage issue along with the stages of R&D such as basic research, exploratory research, application research, and

---

Submitted, July 31, 2017; 1st Revised, August 17; Accepted, August 17
* Strategy and Planning Division, Korea Food Research Institute, Sungnam-si, Gyeonggi-do, 13539, Korea; parkjm@kfri.re.kr
* * silim@kfri.re.kr
* * * Department of Economics, Hannam University; s.s.seol@hnu.kr

development; and the level issue such as person, team, project, program, organization, firm and industry (Ojanen and Vuola, 2003).

If the assessment is applied to the firm's R&D, comparison with public R&D is simple. Most indices of measurement on the firm's R&D are related to sales, costs and returns on investment. If the assessment is for public R&D, assessment becomes more complex and difficult to carry out. In some case, the groups benefiting from R&D outcomes cannot be identified. Also, many outcomes are service types, which are difficult to measure such as enhancing the quality of life, easiness, psychological safety and security. Simply put, Bozeman (2003) explains these difficulties with the concept of public value failure compared to the concept of market failure.

If the assessment is confined to a public institution's R&D on a time horizon, another issue appears adding to the inherent nature of public R&D outcomes. The difference of perception of importance appears over time. In many cases, especially in developing countries, the role of public research institutes has changed as time goes by, from imitation to innovation. So, the issue appears regarding the types of R&D outcomes.

This study proposes a new measuring method of public R&D outcomes. The technology valuation method we introduce is composed of two methods: the scoring method and valuation method for detailed measurement. The scoring method can be used for simple outcomes whether there are visible or not, like Ruegg (2006). The valuation method is used especially for visible outcomes and for the validation of tools used for invisible outcomes. The valuation method is not a single method, but a bundle of methods classifying approach, method and technique. We show the framework of the technology valuation method and apply it to the sample outcomes of a public food research institute that has a 30-year history in Korea.

This article discusses the theoretical basis in section 2 and describes the framework and procedure of technology valuation method. Section 3 shows the scoring procedure through a sample case of public research outcomes. Section 4 offers the valuation of four visible cases. Two results are checked and consolidated in section 5. In that section, we will discuss some theoretical issues as well as reach a conclusion.

II. Methodology

1. Limits of the Existing Literature on Outcome Comparison

Since early 1980s, research assessment was carried out in private organizations by few practitioners: R&D productivity measurement at Hughes

Aircraft Company (Ranftl, 1974), Alchore Labs (Patterson, 1983), Pappas, Richard and Donald (1985) and Brown and Svenson (1988) in IRI Research Technology Management during the 1980s. The methods were mostly market-based as stated by Bozeman "in the U.S. ... "Good research" will automatically be used in the market and to everyone's benefit." (Bozeman, 2003, p.5)

When it comes to public domain of assessment research, there is only one book (Salasin, Hattery and Thomas, 1980) and one paper since early 1980 (Bozeman, 2003). However, many studies and guidelines for public research have appeared since the 1990s. Some examples are Kostoff (1994) for naval research and Parish (1998) for National Academy of Engineering, Science and Medicine, McLaughlin and Jordan (1999) and W.K. Kellogg Foundation (2004) and Ruegg and Feller (2003) for ATP program in the USA. Werner and Souder (1997) review the studies covering the 1956-1995 period.

Ojanen and Vuola (2003) classify assessment methods along five domains: measurement perspective, measurement purpose, measurement level, R&D types and phases of research results. The measurement purpose is focused on decision-making and management of research, in short, effectiveness of R&D. The measurement perspective comes from the customer, internal, finance or interest owner, and others. The diversity of measurement levels refers to person, team, project, program, organization, firm and industry. The R&D types are basic research, explorative research, applied research and development. The phases are classified into input, in-process, output and outcome. Ruegg and Jordan (2007) reviewed 14 methods for the US Department of Energy such as peer review, indicators, bibliometric methods, case study, survey method, and benchmark method, among others.

Jolly et al. (2016) introduced three new methods for assessing public research, adding to the traditional economic methods and case study: Public Value Mapping (Bozeman, 2003), Payback Framework (Donovan and Hanney, 2011), and Social Impact Assessment Method (SIAMPI) (Spaapen and Van Drooge, 2011). The last two methods are characterized by the fact that research output can have impacts through the interaction with society, in particular, stakeholders in SIAMPI and intermediate subjects in Payback Framework.

The process of output to impact is followed: research output of public research is used for policy making and product development, and that becomes the outcome. And, in turn, the result is used by the general public and becomes an impact. In this process, the aforementioned new methods highlight the interaction or mediator during the process.

A question arises: if the research output goes directly to the general public and is used without any interaction or intermediation, how does one measure the impact and how can one compare or select particular research projects or programs over traditional ones?

2. Technology Valuation

Technology valuation is a type of valuation that deals with technology and its business. It deals with future earnings of technology and related business and also past expenses or costs from previous investment. Although technology is one component of intangibles that have a long business history (Alexander, 1962), technology valuation starts from the internal evaluation of technology investment such as examined by Mitchell and Hamilton (1988), Nichols (1994), Faulkner (1996), Ottoo (1998) and Boer (1999, 2000), Seol (2000a, 2000b) and Park and Seol (2006).

Technology valuation became a business service in Korea. Seol, Park and Oh (2012) have written the basic training book for the Korea Valuation Association (KVA), a body that specializes in the valuation of technology and business. There are currently about 2,600 certified valuation analysts in Korea. The valuation standards of KVA are in line with the International Valuation Standards. Seol (2010) discusses some professional issues.

Principles of technology valuation are not that different from any business valuation. It is based on profit expectation. Profit expectation always needs in-depth analysis on all the facets related to technology and business: technology, products, market and industry, market environments, and the ability of business entities. The analysis is composed of a risk analysis and a value driver analysis. An analysis on value driver is important because some value drivers overcome the risks involved, and vice versa. This means that technology valuation is based on a complex analysis of risks and value drivers.

In the course of technology valuation, checklists (for example, Seol and Lee, 2002) are generally used to assess the risks or value drivers to identify the most critical factors. The checklist is composed of five or six domains having many multilayered factors: technology, market, profitability, firm and people. The checklist is used for scoring and simplifying the importance of each factor from the bottom layer to the upper layer. The checklist covers nearly all the factors influencing value. Therefore, practitioners always modify the checklists along with the valuation object. Furthermore, this kind of checklists is used for evaluating public research and technology.

3. Valuation Method in Research Performance Assessment

Public research activities have results as output, outcome and impact (Ruegg and Feller, 2003; Donovan and Hanney, 2011; Park, 2011). If research output is implemented by policy or market, it becomes the outcome. In addition, the outcome becomes impact, if the outcome is used and diffused to related parties. Among these research results, many studies on private research activities omit the impact phase.

In the public domain, however, there are knowledge type outputs that are transferred to the general public as shown in Figure 1. In this process, there is no selection stage according to policy or customer. For example, food or food handling knowledge steer people to the desired direction of food culture. The output becomes outcome and has an impact just after research. If we meet these kinds of output during the assessment, a different approach is needed.

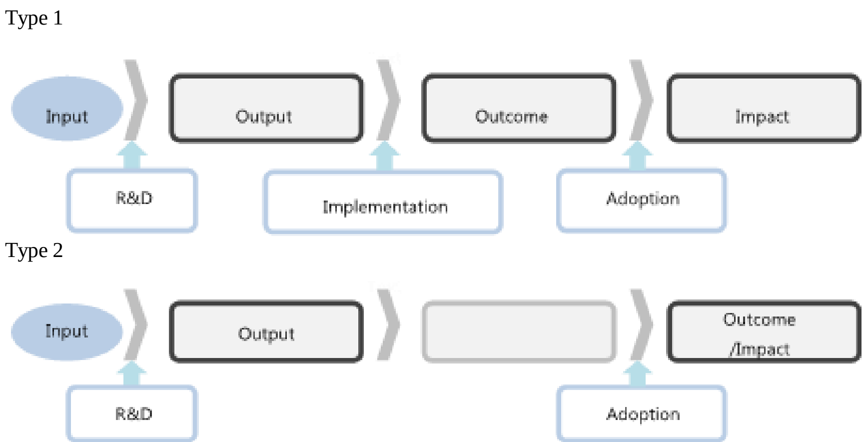

Figure 1 Types of impact of public research

The technology valuation method is a logic model consisting of eight steps of assessment, constituting two different approaches. The model starts from the identification of objects for assessment. In many cases, an output or outcome is a result of different researches. On the contrary, a research yields different outputs. Therefore, a cleaning of output or outcome is needed. In addition, the scope and time span of output or outcome are important at the identification stage.

In step 2, the preliminary value drivers and evaluation table by type of outputs or outcomes are identified. The value drivers are different in output, outcome and impact even if the results come from the same R&D. As current studies pointed out, outcome can have different features according to the role of implementers such as policy or product. Even different companies produce different outcomes with the same output. Hence, the identification of value driver in each type of research result lies in the critical understanding of the objects being assessed. As for valuation, checklists provided by the valuation society can be used as a simple approach.

In step 3, a small focus group is constituted to find out the exact outcomes or impacts. Members of focus groups come generally from the technology, market and investment fields, which are experts in the assessment objects. The group discusses with the research team about the objects or value drivers in order to design the evaluation table.

In step 4, the evaluation table with value drivers by types of outcome is created. The discussion results or opinions from outside experts form the basis for the table.

In step 5, small surveys of experts are done with the evaluation table for types of outcome. Of course, the members of the focus group can be included in the survey. Surveys should have two contents: one for scoring the evaluation table and the second for weighting between types.

In step 6, data handling originates performance evaluation for outcomes and impacts, producing performance index. If there are many objects, the order of scores for each outcome will appear. The transformation of scores to performance index will be shown in the explanatory cases. The question at this stage is whether the order and the degree of difference are correct in mathematical terms?

Step 7 can be excluded if the evaluation is carried out simply for understanding the value driver or risk factors for the outcome or impact. However, if a detailed performance index is wanted, a more in-depth analysis should follow: the so-called case analysis in other studies, or valuation in our terminology. In step 7, the validation process for the comparative index should be done by valuation.

In step 8, the primary performance index is compared to the results of valuation, and adjusted. The adjustment will provide a good fit for the data and the final performance index.

Table 1 Procedures of technology valuation method

Step 1: Identification of objects only (output, outcome etc.)
Step 2: Check out simple value drivers by types of outputs
Step 3: Focus group discussion for deep understanding
Step 4: Construct measurement indices by type of outputs
Step 5: Survey for small experts group
Step 6: Measurement of comparative size
Step 7: Validation
Step 8: Finalizing the measurement

This procedure delineated here is a revised and consolidated version of the procedure for simple analysis of technology value and of technology valuation. The procedure for a simple analysis for technology value is as follows:

identification, analysis finding value drivers and risks, scoring of value driver factors, and finalizing. The procedure for technology valuation is as follows: identification, analysis finding value drivers and risks, measurement of cash flows, application of valuation methods, adjustment, and finalizing.

III. Scoring of Sample Cases

1. Sample Case of Public Food Research

We deal with the outputs of a public research institute in food technology in Korea. The mission of this institute is to provide technology, knowledge and infrastructure for food technology and industry. However, there has been a slight change of mission along with the changes in agriculture and food industry over the past 30 years.

The institute has selected the best outputs from time to time. Since 2008, 59 outputs have been selected from eight trials as best outputs, among which five were the best of the year. However, 15 best outputs measured by the number of media news are quite different from the in-house selection. Therefore, the researchers want to identify what are the best outputs and how much they contribute to the economy during their history.

2. The Procedure

In step 1, we identified the 32 candidate outputs through the merge and split of outputs. An output has a 27-year service across the several stages of research.

In step 2, we classified the outputs into five big categories such as industry, scientific, infrastructure, policy, and knowledge. In this technology area, food knowledge directly trickling down to people is important because of the safety and well-being of the general population. Policy outputs are also important because of the state of emergency in industry and food life.

In step 3, we constituted a focus group made up of four experts from evaluation and public research policy, four valuation analysts, three food industry experts, and three in-house researchers. All the participants have more than 15 years of experience in each domain. The group checked and adjusted all the candidate outputs into 32 outputs, and distributed these outputs into each category. Further, the group checked and modified the scoring indices of each outcome category.

In step 4, we asked the 14 experts among the group members to score each output and weigh each category. Not-attending respondents were high level in each field. The detailed indices for each category will be discussed later. In step 5, we measured the comparative size of the contribution.

In step 6, we identified some outcomes that can be measured in financial terms, because some outcomes are nearly 30 years old. Four outcomes are selected and measured. Prior to measurement, we standardized the research results as the outcome, and the outcome as industrial performance, leaving out other effects and impacts such as social, cultural and human aspects.

In step 7, the valuation results of each output are adjusted with the survey results. This procedure will be discussed in the next section.

3. Scoring by Type of Outcomes

Some old outputs in the industrial type are without data; so all the outputs in this category are measured with three indices such as market size, business period and feasibility. Scoring is based on five Likert styles. The indices for industrial outcomes are as shown in Table 2. The scientific outcomes are measured with the same indices used in industry outcomes.

Table 2 Value drivers for industrial and scientific outcome

Score	Market size	Business life	Feasibility
5	World	More than 10yrs	Firm operation by return
4	Nation	6-10 yrs	Return from investment
3	Multi-sector	4-5 yrs	Income>input
2	Sector	2-3 yrs	Income=input
1	Special product	Temporary	Income<input

Note: Market means economic results from the creation and expansion of the market, and replacement and reduction of existing industry.

The knowledge outcome is measured by four indices such as effectiveness, impact scope, duration and frequency. The infrastructural outcome is measured by scope/coverage, effectiveness, and duration. The indices for policy outcomes are timeliness, scope/coverage, effectiveness, and duration.

Measurement is as follows:

Performance | industrial = (market * life * feasibility) / (5*5*5)

Performance | policy = (scope * life * effectiveness * timeliness) / (5*5*5*5)

Table 3 Value drivers general

	Score				
	5	4	3	2	1
Effectiveness	Full fulfillment	Partial fulfillment	Small fulfillment	Simple improvement	Continuing improvement
Innovativeness	World first	World level	Nation first	Nation leading	Catch-up
Impact scope	World	Nation	Multi-sector	Sector	Special application
Duration	Permanent	Over 10yrs	5-10 yrs	3-5 yrs	Within 1yr
Frequency	Every day	Every week	Every month	Several mo's	Temporary
Response time	Immediately	Within months	Within 1yr	Within 2-3 yrs	Within yrs

Note 1. Impact area covers direct impact.

Between types, the survey measured the comparative degree of contribution. If the industrial outcome is 1, scientific outcome is 0.89, knowledge outcome 0.9, infrastructure outcome 0.99 and policy outcome 1.06.

IV. Valuation of Industrial Outcomes

All the measurements were done under the following assumptions. First, only the industrial outcome was measured. Second, the outcome was measured under finite life conditions following the valuation standards, although some technology has been used for a long period. Third, only the clear contribution was measured even if there were some invisible effects. Fourth, all expenses and outcomes were measured by end of 2016 value. This assumption produces a low estimation of the outcome. Nonetheless, we want to show visible outcomes.

1. Rice Processing Complex

Rice is produced through the process of harvesting, drying, storing, polishing and packaging. Before 1990, each process had been produced separately and naturally in Korea. The only polishing process was implemented by more than 16,000 small facilities and 25% of the storage was handled by government facilities that had a proper system.

This institute developed the rice processing complex (RPC), which integrated all the processes in 1991. RPC replaced rapidly old polishing facilities and it already became the main facility for rice processing in 2000.

Besides, RPC functions as the storage system for rice surplus. In 1990, the rice surplus was about two million tons, 34% of the year production. The number of RPC was 328 in 2001 and some RPCs fell into the red because of competition. This led the government to stop supporting the RPC diffusion. RPC dropped the loss rate from 6% to 1% (Seol et al., 2017).

This institute introduced the second-generation RPC in 2007 and it gradually replaced the old RPC. In 2015, the second-generation facilities numbered 214 while the first-generation numbered 173. The second-generation RPC benefited by size expansion, automation and quality control compared to the first-generation RPC.

As for valuation of the outcome, the assumptions are as follows: for the first-generation, the rate of loss reduction during rice production and new construction of the complex were measured. For the second-generation, a 3-percent royalty on rice production was applied. This figure was the average of three industrial cases and two institute's cases. Technology life span is 10 years for both generations. Legal life for tax purpose was 8 years.

The loss rate is calculated as follows:

Loss reduction = Rice production * distribution rate * installation rate
Note 1 Other grain like barley excluded
2 Distribution rate = rice production – inventory

Table 4 Industrial outcome of RPC (2016 present value, KRW 1 billion)

Effects	RPCⅠ: 1991-00	RPCⅡ: 2007-16
Reduction of loss	1,480	
New construction	1,020	
Royalty		622
Total	3,123	

This is only the outcome from the reduction of rice loss during production. We wanted to add the distribution effects such as reduction of loss from the distribution through small packaging and quality enhancement because of just-in-time polishing. Unfortunately, we could not get data of these kinds of effects.

2. Precooling system

Precooling system keeps fruits and vegetables fresh by maintaining low temperature from harvest to consumer. One feature of precooling is the quick elimination of field heat in fruits and vegetables. Vegetables themselves and various natural ingredients such as vitamin disappear after three to four days. However, precooling keeps vegetables fresh more than 21 days.

Some 211 systems were deployed between 1998 and 2011, accounting for about half of the nation's cooling systems. This system has accelerated the diffusion of similar cooling systems and transformed the nationwide distribution network for fruits and vegetables.

The first vegetable to benefit was strawberry. Before the introduction of this system, the 3-year average export of strawberry until 1998 generated 0.6 million US dollars; it has increased on a yearly average to 7.75 million US dollars by 2011. Another big visible outcome is the reduction of vegetable and fruit loss during distribution. The third benefit is that this system replaced imports.

We assumed the life of this system as 12 years. It is also a system similar to RPC. But, this system is much simpler than RPC, so it is expected to last longer. The strawberry outcome is measured by the creation of an export market, excluding the expansion of the local market. The import replacement outcome was measured as the price difference between imported price (USD 21,500) and the market price of half the import price in 1998.

Loss reduction is calculated adopting the main assumption of Kwak et al. (2012). The amount of distribution of fruits and vegetables is about 1.5 times that of production. The loss during distribution is estimated at 20-30%. About 43.2% of fruits and vegetables are treated through the local distribution agencies and 6.7% of them used the system. Hence, the calculation is

Reduction = distribution amount * technical reduction * diffusion rate

Technical reduction = loss (25%) * reduction (20%)

Diffusion rate = agency distribution (43.2%) * system use (6.7/2%) * installation rate

Table 5 Industrial outcome of the precooling system (2016 KRW 100 million)

	Direct outcome	Power index of dispersion	Total effect
Replacement	561	0.641	921
Market generation	1,262	0.853	2,338
Loss reduction	1,934		3.584
Total	3,757		6,842

Source: Assumptions by Kwak et al. (2012)

In this case, we multiplied the index of the power of dispersion of the Input-Output table since the visible diffusion of a similar system is too clear. The index for import system replacement is 0.641, and market generation and reduction of loss are 0.853. Generally, the power index is not used for loss reduction. But, we think this reduction is not the general reduction, but a kind of market generation.

3. Corn Silk Tea

The institute has developed many drinks using fruits and vegetables, and these developments were the first products in mass production in Korea. This development led the industry to imitate these products because there was no royalty. Even the government encouraged the institute to transfer freely the technologies to industry until 1990s. Corn silk tea, although it was transferred to the industry with royalty, is a good example of drink products having market data.

Corn silk is not eatable, so it has been discarded except for its use in drug material for strengthening kidney and helping the discharge of body waste in Korean traditional medicine. The institute developed a tea drink using corn silk and transferred the technology to industry in 2005. The drink became a 'me-too' product soon after the launch of a company. Other companies imitated it. Indeed, an imitation has become the dominant product in the market ever since it was launched. Therefore, we can use the sales history of the leader.

Sales revenues of the leader were 487 billion Korean Won during 2006-2016 (544 billion at present value) and the product is expected to keep selling for the next 10 years. Corn silk has been imported mostly from China.

If we expand the expected life span to 2026, then the outcome at 2016 present value could reach sales of 957 billion Korean Won. However, we choose 544 billion Won as the outcome of this technology like other validation cases.

4. Ingredient Analysis for Nutrition Labels

Some countries impose nutrition labels on every packaged food and food additives (Hawkes, 2004). Major export countries for Korean food are Japan, USA, China and Russia. The US FDA imposed the nutrition label system since May 1994. US Customs seized about 700 food items because of the absence of labels in 1994. At the moment, it was not possible to analyze ingredients in the industry except in the case of few big companies in Korea. The institute helped conduct the analysis from 1994. It recorded a pick of 467 cases in 1999 followed by a rapid decrease thereafter. The rapid increase in cases until 1999 was the result of Japan implementing a similar policy. Japan imposed the system on packaged food products from May 1996 and put a waiver until 1998.

We chose the royalty method to measure the industrial outcome. The reference cases from similar services or technologies were extracted from history books on technology transfer from 1966 to1995 published by the Korea Industrial Technology Promotion Association. It is the history of the approved or reported Korean technology imports from abroad. The average royalty excluding data at both ends, involving 25 cases was 5%, over a 6.1-year average.

We traced the exported amounts of food products to the USA from 1994 to 2000 and that of Japan's during the 1996-2000 period. The commodity code is 16-24 in the Harmonized System of Korea. We used the statistics DB of the Korea Trade Association. For the products subjected to nutrition label system, we assume half of each export. The assumptions for the ratio serviced was 100% for the first two years, then decreasing by half every subsequent year - a ratio of 0.5, 0.25. 0.125 and 0.0625, from 1996 for exports to the USA. As for exports to Japan, the same ratios applied: 0.5, 0.25. 0.125 and 0.0625, from 1996. This process produced a total outcome of 498 billion Korean Won at 2016 value.

V. Validation of Scoring System

1. Scoring Index in Four Cases

Scoring was done with the Likert scale with one to five factors by factors of each outcome. The group average and total average of scores are shown in Table 6. The performance index is calculated with the equation aforementioned that does not include value at both ends. The index was calculated in a multiplicative manner since all the factors work together, not individually.

The average score of each expert group varies with the total average showing 2.5-48.3% difference in absolute terms. In addition, the scores from each expert have considerable outliers as shown in the minimum and Maximum in Table 6.

The difference in the case of corn silk tea between the average of each group and the total average is very low with only 4.3% in absolute terms, followed by RPC 16.1%, precooling system 21.2%, and ingredient analysis service 26.3%. No generalization is possible because of the small size of samples. This makes us delete one value at both ends for calculating the performance index in the final measurement, to get rid of outlier value.

Table 6 Scoring of cases by experts group

Outcome	Experts	Group avg. A	Total avg. B	(A-B)/B %	Min	Max
RPC	Policy evaluation	0.850	0.696	22.1	0.800	1.000
	Valuation	0.674		-3.2	0.256	1.000
	Food industry	0.520		-25.3	0.360	0.800
Precooling	Policy evaluation	0.358	0.420	-14.7	0.064	0.640
	Valuation	0.542		29.2	0.384	0.800
	Food industry	0.339		-19.3	0.216	0.512
Corn silk	Policy evaluation	0.368	0.377	-2.5	0.160	0.512
	Valuation	0.400		6.0	0.160	0.640
	Food industry	0.360		-4.6	0.120	0.640
Ingredient analysis	Policy evaluation	0.290	0.338	-14.3	0.230	0.410
	Valuation	0.264		-21.9	0.173	0.480
	Food industry	0.501		48.3	0.064	0.800

Note 1. Scores of in-house researchers are omitted.
2. The final index was calculated without value at both ends.

2. Adjustment of Performance Index

If the values we produced through valuation may be truthful, all the scoring indices of measured outcomes should be adjusted based on them. If some values are based on clear facts and data, then the values can be judged as true.

Final performance indices and the estimation results are shown in Table 7. To avoid the confusion in unit difference, comparison 1 and 2 are included in the table. The estimation performance of RPC stands out compared to the surveyed performance. The ratio between RPC and precooling in the survey is 100:59, and the estimation is 100:27. If we exclude RPC outcome and compare the other three cases, both results show a very similar pattern (comparison 2 of Table 6 and Figure 2).

In our cases, RPC has an outlier value although it seems minimum with a clear set of data. So, we may accept the value as true. The next step is the adjustment of remaining scores along with the other three values. Figure 2 shows that three values happen to be similar to the scores. In this case, we can accept the scores without adjustment and can transform the scores of other outcomes into values.

Table 7 Comparison between survey and estimation

	Original		Comparison 13		Comparison 24	
	Survey1	Estimation2	Survey	Estimation	Survey	Estimation
RPC	0.711	2,500	100	100		
Precooling	0.417	684.2	58.6	27.4	100	100
Corn silk tea	0.377	544.3	53.0	21.8	90	80
Ingredient analysis	0.336	498.4	47.3	19.9	81	73

Note 1. Performance index

2. The unit is billion Korean Won. Total outcome of RPC is 3.1 trillion Won. The survey for RPC, however, is based on the outcome of the 1st generation. So, the value of 2.5 trillion Won is for the 1st generation.
3. RPC = 100
4. Precooling = 100

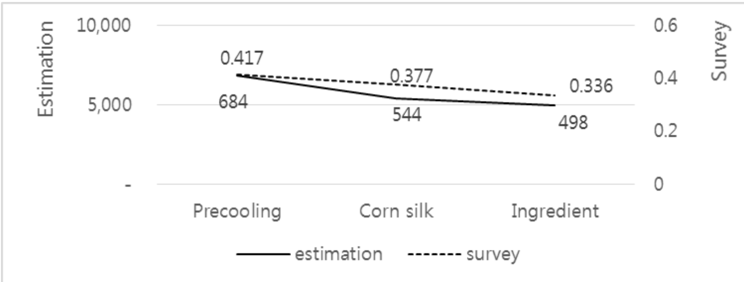

Figure 2 Comparison between survey and estimation, except for RPC

If the values are not well matched with the scores, some techniques are needed, for example regression analysis, to figure out the relational function. In case econometric technique is used, the values from the estimated equation can be accepted as true and applied to other unquantifiable outcomes.

This result points to two facts: First, the scoring system of outcome assessment can be used as a simple alternative for detailed measurement. Of course, this may be true under the circumstance where we construct a careful analytical framework and the framework is well scored by experts in each field. Second, nonetheless, some outstanding outcome can distort the scoring system. This leads us to valuate some measurable outcomes.

VI. Discussion and Conclusion

The assessment of each outcome or impact of public research is always difficult since they include invisible or unquantifiable effects. This is an attempt to perform an assessment of the outcome of public research. The model introduced is designed for the unquantifiable outcome; in particular, knowledge output which is the same with outcome as is with impact. People use some scientific information about food without any interaction between researchers and players in the output (Donovan and Hanney, 2011) or any player in the implementation of output (Spaapen and Van Drooge, 2011). Is knowledge or scientific outcome comparable to the measured outcome? If possible, how big is the unquantifiable outcome? This model can offer an alternative.

The technology valuation method is a logic model that includes eight steps of assessment, organized into two different approaches. The first approach is the scoring by type of outputs or outcomes for the evaluation table. The evaluation table is the result of the focus group discussion. The second approach is to validate the first approach using the traditional technology valuation methods. In fact, the first approach is also based on the simple evaluation technique of technology valuation methods (Seol and Lee, 2002).

The highlight in the application of this model lies in the validation process. In our sample cases, one value from valuation is an outlier, but the value is judged to be true. Therefore, the value can replace the scoring results. In addition, we can take three other values from valuation since scoring results are a good fit of the valuation results.

The use of this model has limitations. There are two types of valuation: financial valuation mainly carried out by practical valuation bodies with market data and economic valuation for unquantifiable objects mainly done by scholars and policy analysts. This model is based on financial valuation techniques with clear or acceptable market data. Therefore, it cannot work solely for unquantifiable outcomes without comparable measurable outcomes, unlike in economic valuation (Kim and Seol, 2015).

The scoring system for assessment like Ruegg (2006) presents several challenging issues. In particular, our model has these kinds of issues: First, the identification of value drivers, or simply affecting factors, is important to apprehend the whole effect of research. We had three steps to fix the factors and the evaluation table: research team, consulting with internal and external experts, and focus group discussion. Personal opinion is limited in nature, so discussion with other experts intends to correct the value drivers and evaluation tables. Second, designing evaluation tables as simple as possible is important. Third, selecting and inviting experts to focus group discussion are also critical.

References

Alexander, D. (1962) Valuations of Intangibles, Institute on Federal Taxation, New York University: NY.

Boer, P.F. (1999) Valuation of Technology: Business and Financial Issues in R&D, Wiley and Sons: NY.

Boer, P.F. (2000) Valuation of technology using real options, Research Technology Management, July-August, 26-30.

Bozeman, B. (2003) Public Value Mapping of Science Outcomes: Theory and Method, School of Public Policy, Georgia Tech.

Bozeman, B. and Kingsley, G. (1997) R&D Value mapping: a new approach to case study-based evaluation, Journal of Technology Transfer, 22, 33-41. DOI: http://dx.doi.org/10.1007/BF02509643.

Bozeman, B. and Sarewitz, D. (2011) Public value mapping and science policy evaluation, Minerva , 49, 1-23. DOI 10.1007/s11024-011-9161-7

Brown, M.G. and Svenson, R.A. (1988) Measuring R&D productivity, Research Technology Management, 31(4), 11-15.

Brown, M.G. and Svenson, R.A. (1988) Measuring R&D productivity, Research Technology Management, 41, 30-35. DOI: http://dx.doi.org/10.3152/095820211X13118583635756

Donovan, C. and Hanney, S. (2011) The 'Payback Framework' explained, Research Evaluation, 20(3), 181-183.

Faulkner, T.W. (1996) Appling options thinking to R&D valuation, Research Technology Management, 50-56.

Hawkes, C. (2004) Nutrition Labels and Health Claims: The Global Regulatory Environment, WHO.

Joly, P.B., Colinet, L., Gaunand, A., Lemaire, S. and Matt, M. (2016) Agricultural Research Impact Assessment: Issues, Methods and Challenges, May, OECD.

Kim, G.H. and Seol, S.S. (2015) Valuation of the stabilization plan for the foot and mouth disease burial sites, Environmental Engineering Review, 20(1), 59-63.

Kostoff, R.N. (1994) The Handbook of Research Impact Assessment, Arlington, VA: Office of Naval Research.

Kwak, C.G., Chang, J.G., Park, J.M. and Park, J.H. (2012) A study on the establishment of strategic functions of Korea Food Research Institute. (Korean)

Lee, K.H. and Seol, S.S. (2002) A comparison of commercial practices on the valuation of intangibles, Journal of Korea Technology Innovation Society, 5(2). (Korean)

McLaughlin, J.A. and Jordan, G.B. (1999) Logic models: a tool for telling your program's performance story, Evaluation and Program Planning, 22(1), 65-72.

Mitchell, G.R. and Hamilton, W. (1988) Managing R&D as a strategic option, Research Technology Management, May-June, 15-22.

Nichols, N. (1994) Scientific management at merck: an interview with CFO Judy Lewent, Harvard Business Review, January-February, 88-99.
Ojanen, V. and Vuola, O. (2003) Categorizing the measures and evaluation methods of R&D performance - A state-of-the-art review on R&D performance analysis, Telecom Business Research Center Lappeenranta, Lappeenranta University of Technology, Working Papers 16.
Ottoo, R.E. (1998) 'Valuation of internal growth opportunities: the case of a biotechnology company' the quarterly review of economics and finance, 38, 615-633.
Pappas, R.A. and Remer, D.S. (1985) Measuring R&D productivity, Research Management, 28(3), 15-22.
Parish, T.D. (1998) The technology value pyramid, national academy of engineering, science and medicine (ed.) Assessing the Value of Research in the Chemical Sciences, 50-125.
Park, J.M. and Seol, S.S. (2006) Valuation of a biotechnology using real options - human genom projects for cancer, Journal of Korea Technology Innovation Society, 9(1), 3.
Park, S.M. (2011) Models and perspectives of outcome assessment, in Park, S.M., Sul, W.S. (eds.) Handbook on R&D Performance Evaluation, Seoul: Korea Studies Information Co.
Patterson, W.C. (1983) Evaluating R&D performance at Alchore Labs, Research Management, 3.
Ranftl, R.M. (1974) R&D Productivity, Hughes Aircraft Company.
Ruegg, R. (2006) Bridging From Project Case Study to Portfolio Analysis in a Public R&D Program: A Framework for Evaluation and Introduction to a Composite Performance Rating System, US: Department of Commerce, National Institute of Standards and Technology (NIST).
Ruegg, R. and Feller, I. (2003) A Toolkit for Evaluating Public R&D Investment: Models, Methods, and Findings from ATP's First Decade (grant/contract report), Gaithersburg: National Institute of Standards and Technology.
Schumann, Jr. P.A., Ramsley, D. and Prestwood, D.C.L. (1995) Measuring R&D performance, Research Technology Management, 38(3), 45-54.
Seol, S.S. and Yoo, C.S. (2002) Professional real options models for the valuation of investments and technology, Journal of Korea Technology Innovation Society, 5(1), 44-58.
Seol, S.S. and Lee, K.H. (2002) A study on checklists for technology, market and firm analysis, Journal of Korea Technology Innovation Society, 5(3), 277-292.
Seol, S.S. (2000a) An analysis of the conceptual framework of valuation of technology, Journal of Korea Technology Innovation Society, 3(1), 5-21.
Seol, S.S. (2000b) The concept and analysis of the valuation of technology, Journal of Korea Technology Innovation Society, 3(2), 1-13.
Seol, S.S. (2010) Some professional issues on the valuation of technology, International Journal of Technology Marketing, 5(2), 145-162.
Seol, S.S. et al. (2017) Economic Effects of Korea Food Research Institute, Korea Valuation Association. (Korean)

Spaapen, J.M. and Van Drooge, L. (2011) Introducing 'productive interactions' in social assessment, Research Evaluation, 20, 211-218.
DOI: http://dx.doi.org/10.3152/095820211X12941371876742

Szakonyi, R. (1994) Measuring R&D effectiveness, Research Technology Management, 37(2), 27-32.

Tipping, J.W., Zeffren, E. and Fusfeld, A.R. (1995) Assessing the value of your technology, Research Technology Management, 38(5), 22-39.

W. K. Kellogg Foundation (2004) W. K. Kellogg Foundation Logic Development Guide, MI Battle Creek.

Werner, B. and Souder, W. (1997) Measuring R&D performance-state of the art, Research Technology Management, 40(2), 34-42.