Return on Agricultural Research and Development Investment in Southeast Asia

Review of Integrative Business & Economics Research

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ABSTRACT

This study examines the impact of research and development (R&D) on total factor productivity in the agricultural sector of Southeast Asia, taking into account the effects of COVID-19, and calculating the internal rate of return (IRR) on agricultural R&D investment. Econometric methods were applied to the panel data of eight Southeast Asian countries for the period of 2000–2022. The results showed that agricultural R&D investment significantly raised agricultural productivity in Southeast Asia and that its return was worthwhile at an average rate of 25.72 percent. Therefore, government policies should continually promote agricultural R&D investment. Budget allocation to R&D activities will yield a worthwhile return and benefit the whole community of Southeast Asia.

Keywords: Agricultural Research, Rate of Return, Southeast Asia.

Received 10 January 2023 | Revised 17 April 2023 | Accepted 5 May 2023.

1. INTRODUCTION

Research-induced productivity growth is widely recognized as an important source for sustaining long-term growth in agriculture. In particular, investing in agricultural research is an important policy tool to strengthen the agricultural sector of many developing economies, ensuring food security and poverty reduction, and transforming developing economies to be more productive while approaching inclusive growth (Alisjahbana *et al*., 2022; Even and Pray, 1991; Isik, 2018; Lee *et al*., 2017; Suphannachart, 2019; Warr and Suphannachart, 2021). Empirical evidence from various countries confirms that while returns on agricultural research investments have been high and worthwhile, many countries have been underinvesting in agricultural research (Alston *et al*., 2000; Evenson, 2001; Pardey *et al*., 2006; Stads *et al*., 2020; The World Bank, 2007).

A recent report by Agricultural Science and Technology Indicators (Stads *et al*., 2020) found that Southeast Asia has made considerable progress in building and strengthening its agricultural research and development (R&D) capacity. Nonetheless, regional agricultural research spending has remained stagnant, despite considerable growth in agricultural output over time. The intensity of Southeast Asia's agricultural research—that is, agricultural research spending as a share of agricultural GDP—steadily declined from 0.50 percent in 2000 to just 0.43 percent in 2022. Although some countries, such as Thailand and Malaysia, have been able to increase their agricultural research intensity, none of them

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

have reached the 1 percent target set by the United Nations (Flaherty *et al*. 2013), as shown in Figure 1.

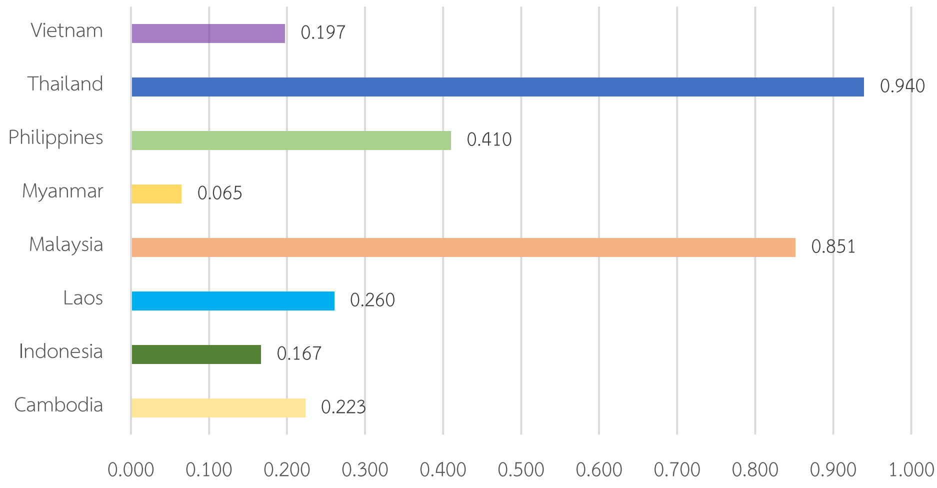

Figure 1. Agricultural R&D spending in Southeast Asia as a percentage of agricultural GDP, 2000–2022.

Source: Agricultural Science and Technology Indicators, 2022; Stads *et al*., 2020.

To address future challenges to agricultural production and ensure productivity growth across Southeast Asia, the region will need to substantially increase its investment in agricultural research. However, Stads *et al*. (2020) did not conduct a statistical test on how regional investment in agricultural R&D affects the aggregate productivity of the region. Therefore, this study aims to fill this gap in knowledge by using an econometric technique to estimate the effect of agricultural R&D on productivity as well as to calculate the internal rate of return (IRR) on agricultural R&D investment in Southeast Asia, which currently exists for only a few countries (Evenson and Pray, 1991; Sequeros *et al*., 2020; Suphannachart and Warr, 2011). Empirical evidence is important in enabling the region to evaluate its past investments and to reconfirm other possible policy tools to stimulate productivity growth.

This study will take the Covid-19 pandemic into account when investigating the role of agricultural R&D on total factor productivity (TFP), because it likely affected the working hours of labor and other factors that affect the TFP. For example, the spread of Covid-19 could have led to budget cuts in agricultural R&D spending and possible suspension or delays in certain R&D operations and activities (Stads *et al*., 2020). This disease outbreak variable was newly added to our analysis and is considered a case-specific factor. In addition to agricultural R&D and the Covid-19 outbreak, the analysis includes other determinants of agricultural TFP, such as irrigation, trade openness, and rainfall. Country-specific factors, such as different values, culture, and geography, are incorporated through the fixed effects (FE) model commonly used for a panel data analysis. A panel of eight Southeast Asian countries includes those where the agricultural sector plays a vital role in their economic development, namely Cambodia, Lao PDR, Indonesia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam. The study covers the period from 2000

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to 2022. The marginal IRR (MIRR) was computed for the region to evaluate the current status of Southeast Asia in terms of R&D investments and for future budget allocation among various competing sources.

2. LITERATURE REVIEW AND THEORETICAL BACKGROUND

As TFP is measured based on the economic theory of the production function, the factors affecting a change in TFP can also be identified by the production function. This study employs measures of TFP using the growth accounting framework, which measures TFP as a residual after accounting for the weighted average of conventional input growth. Hence, several factors determining the TFP are captured in unconventional inputs, which can be categorized into three main groups: (1) pure technical change, (2) efficiency gain, and (3) economies of scale (Coelli *et al.*, 2005).

First, pure technical change is identified by a shift in the production function, where more output can be achieved using fewer or the same number of inputs. Conceptually, technical change is explained based on endogenous growth theory or the new growth theory (Romer, 1990; Aghion and Howitt, 1998). In the new growth theory, productivity growth representing technological progress can be explained endogenously. Advances in technology are recognized as an endogenous process that has systematic and predictable effects on output and productivity growth; therefore, policy measures enhancing technology and innovation through R&D spending are key factors affecting TFP. In the context of agriculture, agricultural R&D and agricultural extension are often used as the main variables representing pure technical change (Alston *et al.*, 2000; Evenson 2001; Evenson and Pray, 1991; Isik, 2018; Liu *et al*., 2020). Other relevant variables that might have improved technological innovation and hence productivity-induced economic growth are capital investment, foreign direct investment, and land-population density (Becker, Glaeser and Murphy, 1999; Bounsaythip and Inthakason, 2022; Dheera-aumpon, 2024). Second, efficiency gain is a movement toward the production function. This movement can be represented by an infrastructure, such as roads and irrigation, and resource allocation, such as an economic transformation representing a shift in labor from a less productive to a more productive sector (Alisjahbana *et al*., 2022; Suphannachart and Boonkaew, 2019). Third, economies of scale refer to a movement along the production function toward the optimal scale at the point where maximum productivity can be achieved. This movement is mostly represented by trade openness—that is, the value of agricultural exports and imports as a share of agricultural GDP. Besides the three main components, non-economic variables potentially affecting residual TFP, such as weather, epidemics, and natural disasters, can be examined (Evenson, 2001; Isaksson, 2007; Suphannachart and Warr, 2011). The outbreak of Covid-19 can be included under case-specific factors. Figure 2 broadly summarizes the key factors determining TFP growth in the context of agriculture.

Since technologies produced by R&D have no obvious prices, it is not easy to determine whether there has been overinvestment or underinvestment. Therefore, the effectiveness of research expenditures is determined by calculating the IRR. The IRR on R&D investment can be compared with other returns on investment as they are measured in percentages. Regarding the method of calculating the IRR, when measuring the returns on R&D investment at an aggregate or national level, the regression-based method is commonly employed (Alston *et al*., 2000; Evenson, 2001; Suphannachart, 2015). This method

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typically uses regression to find a statistical relation between past R&D expenditures and changes in productivity. The computed rate of return is based on the estimated coefficient of the R&D variable, usually derived from the productivity function, which is referred to as the MIRR. The effectiveness of research is usually measured as an MIRR because it is useful for making decisions on additional investments. It is referred to as 'marginal' because the research benefit is estimated based on the marginal effect of research on productivity, and the net return is calculated as per unit of additional investment. Conceptually, calculating the MIRR is similar to finding an IRR on an investment by a firm or household. The IRR is defined as the rate of interest which equates the flow of costs and the flow of benefits over time.

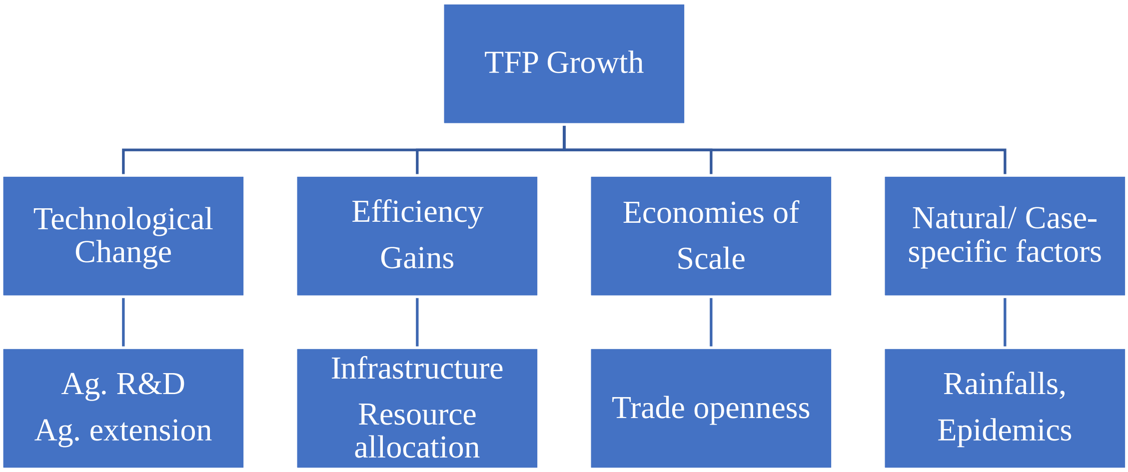

Figure 2. Key factors determining the growth of agricultural productivity
Source: Adapted from Coelli *et al*. (2005) and Suphannachart and Warr (2011).

The MIRR of research investment is the value of r, which satisfies

$$\sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t} = 0 \qquad (1)$$

where B_t is the benefit of research in year t, C_t is the cost or expenditure on research in year t, r is the IRR, and T is the life of the streams of research benefits and costs (full duration of the effects of the research).

The criterion for evaluating research investments is that an investment is worthwhile if it yields positive returns and has an IRR greater than the opportunity cost of funds. When a publicly financed R&D investment is evaluated, its measured IRR is often compared with the yield on government bonds, which is considered the government's opportunity cost of funds. A high rate of return, usually returns of 20 percent or more, implies an underinvestment, suggesting that additional investment in agricultural research is desirable (Evenson, 2001; The World Bank, 2007). Although existing studies have found a wide range of rates of return on agricultural R&D investment, numerous studies have provided evidence of high MIRRs for agricultural R&D in various countries and commodities (Alston *et al*., 2000; Evenson, 2001; Pardey *et al*., 2006; The World Bank, 2007). Flaherty *et al*. (2013) showed that the accelerated growth of global agricultural R&D spending has

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yielded very high payoffs. The rate of return on agricultural R&D investment for developing countries as a whole is 82 percent, and for countries that achieved remarkable growth in R&D spending, such as China and Brazil, the returns are 136 percent and 176 percent, respectively. Evenson and Pray (1991) compiled a regression-based analysis and found that the rates of return on agricultural R&D investments in Asia ranged from 19 to 218 percent. Stads *et al*. (2020) recently examined the current status of agricultural R&D in Southeast Asia and projected the regional TFP growth and agricultural R&D spending from 2016 to 2050 showing that accelerating regional R&D investment would have a substantial impact on the TFP; however, the report failed to obtain the measured MIRR for the whole region.

3. DATA AND METHODOLOGY

This study employs panel data from eight countries whose agricultural sectors play vital roles in Southeast Asia: Cambodia, Lao PDR, Indonesia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam. The period covered was 2000–2022. Altogether, there were 184 observations. Since the objectives of this study are to (1) investigate the effect of agricultural R&D investment on agricultural TFP and (2) measure its rate of return on R&D investment in Southeast Asia, the employed data include agricultural TFP as the dependent variable and agricultural R&D along with other potential determinants as the explanatory variables. Agricultural R&D is measured as a research intensity ratio or expenditure on agricultural R&D as a share of agricultural GDP because the agricultural sectors in each country are of different sizes. Expressing this variable as a percentage share of the agricultural output or GDP shows each country's attention and comparable investments in agricultural R&D. Due to data constraints, only some variables mentioned in Figure 2 are included in the regression analysis. These are shown in Table 1. Note that the data for some countries are missing, and these were estimated using linear interpolation and extrapolation, following the same technique as in Suphannachart and Warr (2011).

Table 1. Summary of Variables and Data Sources, 2000–2022

Variables (abbreviations)	Definitions	Data Sources
Total factor productivity (TFP)	TFP indices measure the amount of agricultural output produced from the combined set of land, labor, capital, and material resources employed in farm production. They were calculated using the growth accounting method and converted to indices using 2015 as a base year.	United States Department of Agriculture (USDA) (2022)
R&D investment (RD)	Agricultural research spending as a share of agricultural GDP	Agricultural Science and Technology Indicators (ASTI) (2022)
Irrigation (Irri)	Irrigated areas for agriculture (1,000 hectares)	Food and Agriculture Organization (FAO) (2022)
Trade openness (TO)	Sum of agricultural exports and imports as a share of agricultural GDP	The World Bank (2022)

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Rainfall (Rain)	Annual average rainfall (millimeters)	World Meteorological Organization reported by Food and Agriculture Organization (FAO) (2022)
Covid-19 (Covid)	Numbers of confirmed cases of Covid-19	World Health Organization (WHO) (2022)
Capital investment (Kinv)	Gross capital investment as percentage share of GDP	The World Bank (2022)
Land-population density (Lpop)	Population density is midyear population divided by land area in square kilometers. (Person per sq. km)	Food and Agriculture Organization and World Bank population estimates. (The World Bank, 2022)

The methodology used in this study consists of two steps and follows procedures similar to those used in previous studies (Suphannachart and Warr, 2011; Suphannachart, 2016). First, the TFP determinant model is estimated using panel data techniques and the FE and random effects (RE) models. The Hausman test was used to determine whether the FE or RE model was more suitable. The null hypothesis under the Hausman test is that the coefficient of the FE model is the same as that of the RE model. If the null hypothesis is rejected, we conclude that the FEs correlate with the explanatory variables. Hence, the omitted variable bias is a problem, and the FE model is preferred (Wooldridge, 2006). The agricultural TFP determinants model incorporates factors affecting the four main components shown in Figure 2, that is, technological change (represented by agricultural R&D intensity ratio), efficiency gain (represented by irrigation are), economies of scale (represented by trade openness), and natural or case-specific factors (represented by rainfall and confirmed cases of Covid-19). Capital investment and land-population density are also added as the higher investment and denser population might accelerate technological innovation, represented by the TFP. Note that the FE model also captures other unobservable country-specific factors. Research lags are incorporated to allow for research benefits, which usually take a certain period of time to reap. In stylized form, the model can be written as follows:

$$\text{TFP} = f(\text{RD, Irri, TO, Rain, Covid, Kinv, Lpop}) \quad (2)$$

where TFP denotes the agricultural TFP indices, RD is agricultural research spending as a share of agricultural GDP, Irri is irrigation area, TO is trade openness, Rain is rainfall, Covid is the outbreak of Covid-19, Kinv is capital investment, and Lpop is land-population density. Note that all variables are expressed in natural logarithms except Covid, as the pandemic only occurred in 2020. All coefficients can be interpreted as elasticities, with a percentage change in TFP corresponding to a percentage change in each explanatory variable. The estimated coefficient of an RD variable represents the effect of agricultural research on TFP in Southeast Asia. It is used to compute the return on R&D investment in the second step.

The second step involves calculating the MIRR on agricultural R&D investment for Southeast Asia as a regional group. This calculation is an annual average rate of return that

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equates the net present value of agricultural R&D investment to zero, as shown in Equation (1). The regression-based effect of agricultural R&D on TFP is estimated as the elasticity *e* of TFP with respect to the research. It is used to calculate the value marginal product (VMP) of research or the marginal benefit of agricultural R&D on agricultural output *Q*. The formula for calculating the VMP is

$$VMP_t = \frac{\Delta Q_t}{\Delta R_{t-i}} = e_i \frac{\overline{TFP_t}}{\overline{R_{t-\iota}}} \frac{\Delta Q_t}{\Delta TFP_t} \quad (3)$$

where e_i is the elasticity of TFP at year *t* with respect to agricultural research at year *t-i*, Q_t is real agricultural output at year *t*, R_{t-i} is agricultural R&D spending at year *t-i*, and TFP_t is the agricultural TFP index at year *t*.

A general procedure for finding the MIRR is that which satisfies discounted VMP – 1 = 0, meaning that a discount rate that equates a stream of net returns from one currency unit investment in agricultural research to zero. This regression-based rate of return is calculated as the discount rate *r*, such that

$$\sum_{t=1}^{T} [\frac{VMP_t}{(1+r)^t}] - 1 = 0. \quad (4)$$

The MIRR *r* equates a stream of discounted benefits to an initial investment of one dollar; therefore, the net present value of a one-dollar investment is equal to zero. The research cost of one dollar occurs in year 0, while the research benefit begins from year 1 to T.

4. RESULTS AND DISCUSSION

The results from the first step are a regression analysis of potential factors affecting agricultural TFP in Southeast Asia. Table 2 summarizes the variables used in the TFP determinant model. The correlation between unobserved country-specific heterogeneity and the explanatory variables is confirmed when the Hausman test suggests that the FE model is suitable. This means that the coefficients of FE are statistically different from those of the RE model; hence, omitted variable bias is a significant problem. Table 3 shows the estimated results from the FE model. Note that the capital investment and land-population density were dropped from the final model because they are not statistically significant and dropping them improving the overall significance of the model. This could be due to the fact that both capital and land variables are already taken into account when calculating the agricultural TFP using the growth accounting method. Therefore, it is not necessary to include capital and land in the TFP determinant model. In addition, due to data constraints, these variables are available at the national level while the other variables are at the agricultural sector level. Particularly, there were a number of missing data for Myanmar and Lao PDR, hence, estimating the missing series could have biased the true variables and dropping them should yield more reliable results.

According to Table 3, the effect of agricultural R&D on TFP is confirmed with an elasticity of 0.0484, implying that a 1 percent increase in agricultural R&D intensity will help boost the agricultural TFP of the whole region by approximately 0.05 percent. This result is consistent with the theory and findings of previous studies (see, e.g., Liu *et al.*, 2020; Suphannachart and Warr, 2011). The other factor significantly affecting agricultural TFP

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is irrigation, which means that the greater the investment in an infrastructure, such as irrigation, the higher productivity the whole region will have. The Covid-19 outbreak did not appear to be statistically significant, possibly because the period (2000–2022) included in the study is too short.

Table 2. Summary Statistics of Variables in the TFP Determinant Model, 2000–2022

	Variables				
	Mean	Std. Dev.	Minimum	Maximum	Observations
ln TFP	1.96	0.87	1.69	2.15	184
ln RD	0.42	0.39	0.03	1.88	184
ln Irri	3.18	0.54	2.43	3.83	184
ln Rain	0.75	0.26	-0.70	1.02	184
ln TO	1.93	0.25	1.07	2.34	184
Covid	233,967	1,180,166	0.00	13,300,000	184
Kinv	1.39	0.10	1.12	1.60	184
Lpop	2.03	0.32	1.36	2.58	184

Table 3. Factors Affecting Agricultural TFP in Southeast Asia, 2000–2022

Variables	Coefficients (Standard errors)
Constant	1.7991
ln RD	0.0484 (0.0107)***
ln Irri	0.0396 (0.0074)***
ln TO	0.0869 (0.1485)
ln Rain	0.0176 (0.1972)
Covid	-0.0000 (0.0000)
Hausman Test	15.82
Adjusted *R*-squared	0.2365

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F-statistic	12.15
Number of observations	184

Note: The level of statistical significance is denoted by * = 10 percent, ** = 5 percent, and *** = 1 percent.

The second step involved measuring the return on agricultural R&D investment for Southeast Asia. We converted the estimated elasticities from the first step into VMPs, which are the benefits of an R&D investment, and we computed the IRR for a 1-unit cost of an investment (Equation 4). The MIRR is estimated at 25.72 percent, as shown in Table 4. Note that the elasticities for 10 years are estimated separately for each year due to data constraints. It is difficult to include sufficient lags in one estimation, as the time-series data are only available for 22 years. The significance of agricultural R&D on TFP was confirmed for the 10-year period.

Table 4. Calculating the MIRR on Agricultural R&D Investment in Southeast Asia

Year	Elasticities	VMPs
1	0.0484	0.0303
2	0.0444	0.0279
3	0.0398	0.0250
4	0.0335	0.0210
5	0.0289	0.0181
6	0.0256	0.0161
7	0.0236	0.0148
8	0.0212	0.0137
9	0.0210	0.0132
10	0.0186	0.0117
		Σ VMP = 0.08061
		IRR = 25.72%

The computed MIRR of 25.72 percent is greater than the average yield on government bonds, which is considered the opportunity cost of public funds. This finding implies that agricultural R&D investment is worthwhile and deserves continued support from the government and all parties involved. The estimated MIRR is consistent with previous studies, which typically found a rate of return on R&D investment greater than 20 percent (Evenson and Pray, 1991; Evenson, 2001; Suphannachart, 2016; Suphannachart and Warr, 2011). This high rate of return implies an underinvestment in agricultural R&D investment, which is common in developing countries (Flaherty *et al*., 2013; Stads *et al*., 2020). The region will need to increase and strengthen agricultural R&D investments not only for the economic benefit of improving agricultural productivity, but also to raise the living standards of people in Southeast Asia.

5. CONCLUSION

Advances in agricultural technology through R&D investments have been proven to increase agricultural productivity in Southeast Asia during the period 2000–2022. These productivity-based benefits can be quantitatively measured as having an average rate of return of 25.72 percent, which is a high and worthwhile return for the region. Amid several

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

challenges that might affect budget cuts in R&D, including the Covid-19 outbreak, the results from this study can assure policymakers in each country studied that continued support in agricultural R&D investment will return worthwhile benefits. This is a long-term investment and requires strong commitment from all countries in the region.

Many studies have proven that research-induced productivity growth, as mentioned in the introduction, will benefit the region in terms of food security, poverty reduction, income inequality, inclusive growth, and improved living standards. The policy recommendation is that continued public support and investment in agricultural R&D is important and needs to be strengthened immediately. An increase in agricultural R&D spending will lead to improved productivity growth, which is a common policy goal in Southeast Asia. The ministries in charge of the development of the agricultural sector can enhance the growth of productivity by increasing their R&D spendings and providing relevant support for R&D, for example, providing grants to fund basic research at universities, building the basic infrastructure necessary for conducting R&D, and encouraging collaborative R&Damong public and private sectors.

ACKNOWLEDGEMENT

The authors thank the anonymous referees for their helpful suggestions.

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